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INDIAN AGRICULTURAL
RESEARCH INSTITUTE, NEW DELHI.

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TRANSACTIONS

AND

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE

VOL. 63
(Quarterly Issue)
Part [illegible], FEBRUARY, 1933

EDITED AND PUBLISHED UNDER THE AUTHORITY OF THE BOARD
OF GOVERNORS OF THE INSTITUTE

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PROCEEDINGS
OF THE
NEW ZEALAND INSTITUTE
1932

ANNUAL MEETING OF THE BOARD OF GOVERNORS,
19th MAY, 1932.

MINUTES.

The Annual Meeting of the Board of Governors of the New Zealand Institute was held in the Biology Lecture Hall, Victoria University College, Wellington, on Thursday, 19th May, 1932, at 10 a.m.

Professor H. W. Segar, President, occupied the chair.

Present: Government nominees—Mr B. C. Aston and Mr W. R. B. Oliver; representing Auckland Institute—Professors H. W. Segar and F. P. Worley; representing Wellington Philosophical Society—Professor H. B. Kirk and Dr E. Kidson; representing Philosophical Institute of Canterbury—Dr C. Coleridge Farr and Professor R. Speight; representing Otago Institute—Mr G. M. Thomson; representing Nelson Institute—Professor T. H. Easterfield; representing Manawatu Philosophical Society—Mr M. A. Eliott; representing Hawke's Bay Philosophical Institute—Mr G. V. Hudson. Dr L. Cockayne, Government nominee, attended in the afternoon.

Apologies for absence were received from his Excellency the Governor-General, the Right Hon. G. W. Forbes, Minister of Scientific and Industrial Research, Professor J. Park, and Dr E. Marsden.

Presidential Address: Professor Segar delivered his presidential address, and asked members to rise in respect to the memory of the following members of the Institute who had died during the year:—Dr J. P. Lotsy, of Holland, an honorary member of the Institute, Mr Elsdon Best, Mr John Kenderdine, Dr H. T. Ferrar, and Dr F. G. Maskell.

At the conclusion of his address Professor Segar was thanked, and was asked to allow his address to be printed in the *Transactions.*

Motions of Sympathy: On the motion of Dr Farr the following resolutions were carried unanimously:—

"That the Institute learns with regret of the ill-health of Dr L. Cockayne, F.R.S., and assures him of its great sympathy."

"That the Institute learns with great regret of the illness of Dr E. Marsden, and trusts that his health may be speedily and permanently restored."

Notices of Motion were then received.

Fellowship Election: The election to fill two vacancies in the fellowship was then proceeded with, and the Hon. Returning Officers reported that Mr G. Archey and Mr T. Rigg had been duly elected.

Hector Award: The President then read the report of the Hector Award Committee as follows: "It is our sad duty to refer in the first place to the death of one of the committee, Mr Elsdon Best, which took place on September 9 last. No sounder advice could be obtained on matters pertaining to ethnology in New Zealand than that which Mr Best, from his long association with the Maori and with those that studied the race, and his eminently sound judgment, was able to give. Mr Best was consulted by one of the members of the committee before he died, so that the recommendation which we have now to make is the unanimous opinion of the three members of the committee appointed last year by the Board of Governors.

"We recommend that the Hector Medal and Prize for 1932 be awarded to Dr Te Rangi Hiroa (P. Buck) for his thorough and highly technical work on Maori arts and crafts, and more especially for his accurate and detailed descriptions of the technique of Maori textile work."

(Signed) W. R. B. OLIVER (Convener).
H. D. SKINNER.

The recommendation that Dr Te Rangi Hiroa be awarded the Hector Medal was heartily approved by the Board.

Amount of Hector Award: On the motion of the Hon. Treasurer, Mr Eliott, it was resolved that the amount of the Prize for 1932 be £60.

Hutton Award: The Vice-president announced that the Convener of the Hutton Award Committee was absent in the country, and he had not been able to forward the recommendation of the Hutton Award Committee. It was resolved to ask the Standing Committee to make the award when the Award Committee's report is available.

Honorary Members: Dr Kidson asked leave to make a statement regarding the qualifications of one of the nominees, and this was granted. The election of one honorary member was then proceeded with, and resulted in Mr Frederick Chapman, of Melbourne Museum, being elected.

Declaration of Vacancies in Honorary Members' List: The death of Dr J. P. Lotsy, of Velp, Holland, was announced.

Incorporated Societies' Reports and Balance Sheets: The reports and balance sheets of the following societies were then laid on the table:—Auckland Institute for the year ending 31st March, 1932; Wellington Philosophical Society for the year ending 31st October, 1931; Philosophical Institute of Canterbury for the year ending 30th September, 1931; Otago Institute for the year ending

30th November, 1931; Nelson Philosophical Society for the year ending 30th September, 1931; Hawke's Bay Philosophical Institute for two years ending 31st December, 1931. No report was received from the Manawatu Philosophical Society, which has not yet been resuscitated.

REPORT OF THE STANDING COMMITTEE FOR THE YEAR ENDING 31ST MARCH, 1932.

Meetings: Eight meetings of the Standing Committee have been held during the year, the attendance being as follows:—Mr Aston, Wellington, 8; Dr Cockayne, Ngaio, 4; Mr M. A. Eliott, Palmerston North, 1; Professor C. Coleridge Farr, Christchurch, 2; Mr G. V. Hudson, Wellington, 8; Professor H. B. Kirk, Wellington, 7; Dr E. Kidson, Wellington, 1; Dr Marsden, Wellington, 5; Mr W. R. B. Oliver, Wellington, 8; Professor H. W. Segar, Auckland, 1; Hon. G. M. Thomson, Dunedin, 6.

The Finance Committee has also met several times.

Board of Governors: The only changes which have taken place on the Board are as follows:—Dr E. Kidson was appointed to represent the Wellington Philosophical Society with Professor Kirk, and Mr G. V. Hudson was appointed to represent the Hawke's Bay Philosophical Institute in place of Mr C. F. H. Pollock, who had resigned that office.

Finances: The financial position of the Institute has been the dominant matter for attention during the year. In view of the fact that the Government had reduced the annual grant from £1500 to £750, and that the Treasury had deducted from the first quarterly instalment of the reduced grant an amount of £149, the balance then owing to the Government Printer, efforts were made to find some means of augmenting the Institute's resources. The incorporated societies were asked to consider various proposals, such as increasing the levy, paying the travelling expenses of representatives attending the Annual Meetings, holding of an art union, etc., but none of them met with general approval. Other proposals which have been considered were the charging of a yearly fee to all Fellows of the Institute, creating an associateship of the New Zealand Institute with direct subscription to the Institute, charging members the full price for the *Transactions.* None of these was approved, but a subcommittee was set up to consider the constitution of a new Society.

The Finance Committee made the following recommendations, which have been adopted:—That the Endowment Fund be increased so that it would yield in future a greater amount of revenue for the purposes of the Institute, and that all proceeds received from sales of Institute's publications from 1st April, 1931, be credited to the Endowment Fund; that the actual reasonable administration expenses be charged against the various Trust Accounts; that the societies be asked to assist by paying the levy before the whole of the volume is published; that the publication of the *Transactions* be continued under the strictest supervision of the Standing Committee.

An appeal to members of the Institute was also decided upon, but owing to certain objections this was not carried out, although one of the incorporated societies, the Philosophical Institute of Canterbury, made an appeal on behalf of the Institute, with the result that a donation of £5 was received.

Authors who had presented papers for publication were asked if they could contribute towards the cost of the publication of these, and £17 7s 9d was thus contributed.

In the Research Grant Fund an amount of £440 had accrued from grants which had been relinquished or refunded since 1921. The Vice-president made representations to the Treasury to have this amount transferred to the General Fund of the Institute for publication expenses, and this was done by a special vote of Parliament in the Supplementary Estimates last year. This considerably relieved the financial position, and enabled the printing of Volume 62 to be proceeded with.

Subsequently the recommendation in the National Expenditure Commission's Report to reduce the Institute's grant still further to £400 was received with great concern. A letter signed by the President stating the position of the Institute, the reductions which had already been inflicted, and protesting against further reduction was sent to every member of Parliament and of the Legislative Council. Several sympathetic replies have been received.

It is understood that the amount of the Institute's grant for expenses will be £500, instead of the £400 recommended by the National Expenditure Commission.

Travelling Expenses: The Auckland Institute's suggestion that a pooling scheme for paying the travelling expenses of members of the Board attending Annual Meetings was agreed to by the other incorporated societies, and at the last meeting of the Standing Committee it was decided to adopt this course for last year's expenses and for future meetings until the finances of the Institute improve.

Publication Matters: As the Institute's finances were so uncertain, it was considered impracticable to sign a contract with the Otago Daily Times Company for any period. The Company was approached, however, to see if it would publish the remaining parts of Volume 62 at the price quoted for a three years' period, and it agreed to do this. A reduced volume has therefore now been completed, and the new printers have proved quite satisfactory.

It has been decided to proceed with the publication of Part 1 of Volume 63 of approximately 100 pages.

Hon. Editor: On the 30th June the Hon. Editor, Professor Sommerville, asked to be relieved of his office for the time being, as he was about to leave for England. A hearty vote of thanks was accorded to Professor Sommerville for his excellent services during the term of his office as Hon. Editor, and the best wishes of the Standing Committee for a pleasant holiday extended to him.

It was resolved that during the absence of Professor Sommerville the Chairman of the Standing Committee, which is the Publications Committee, act as Hon. Editor. It was further resolved that the duty of the Publications Committee shall be to determine what papers shall be accepted for publication, and that every paper shall be submitted to a referee before acceptance. The Editorial Committee shall in each case come to a conclusion as to the probable cost of printing. Papers shall then be passed on to the Hon. Associate Editor, the Hon. G. M. Thomson, who, with the assistance of a Committee co-opted by him, shall be responsible for seeing it through the printing house and for all editorial work.

Professor Sommerville was absent for eight months, and the Institute is greatly indebted to the Hon. G. M. Thomson for the work which he undertook in bringing out Volume 62, the initial volume of the new printers.

Transactions: Volume 61 was laid on the tables of the House of Representatives and of the Legislative Council in June of last year, and Volume 62 will be presented in the ordinary session of Parliament this year.

Sales: The net proceeds from sales of publications during the year amounted to £113 19s, which, under resolution of the Standing Committee of the 30th June, has been credited to the Endowment Fund.

Endowment Fund: At a meeting of the Finance Committee held on 15th September it was recommended that the Standing Committee arrange for the preparation of an Endowment Fund Declaration of Trust. This matter was deferred.

Exchange List: No additions have been made to the Exchange List during the year.

Library: The Library continues to be used extensively by the Staff and Honours students of Victoria University College, as well as by members of the Institute, and many volumes have been posted to members residing out of Wellington. The congestion in the Library is proving a very serious problem for the Librarian.

Carnegie Corporation of New York: Towards the end of last year Professor Coffman, of Michigan University, came to New Zealand representing the Carnegie Corporation of New York. Very generous treatment by the Carnegie Corporation has been accorded to the University Libraries in New Zealand and to certain educational activities. The President and Vice-president interviewed Professor Coffman on behalf of the needs of the Institute Library; he was quite sympathetic, and asked for a comprehensive statement regarding the Institute to place before the Carnegie Corporation. This was sent to him, together with specimen volumes of the *Transactions.*

Professor Coffman has not yet reported the result of his representations regarding the Institute.

Incorporated Societies: The following reports and balance sheets have been received from the incorporated societies:—

Philosophical Institute of Canterbury, for the year ending 31st October, 1931;
Otago Institute, for the year ending 30th November, 1931;
Nelson Institute, for the year ending 30th September, 1931;
Auckland Institute, for the year ending 31st March, 1932;
Wellington Philosophical Society, for the year ending 31st October, 1931;
Hawke's Bay Philosophical Institute, for the period ending 31st December, 1931.

There was no report available from the Manawatu Philosophical Society.

Vice-president: At last Annual Meeting a Committee was set up to define the duties of the recently established office of Vice-president. The Committee's recommendations were adopted at a meeting of the Standing Committee on the 30th June as follows:—

1. The Vice-president shall represent the President on all occasions when he is unable to be present unless otherwise determined by the Board, and shall exercise all the President's executive functions when he is unable to be present in Wellington.

2. The Vice-president shall be *ex officio* a member of all Committees.

3. The President and Vice-president represent the New Zealand Institute on the Dominion Museum and National Art Gallery Board of Trustees (see Dominion Museum and National Art Gallery Act, 1930). Should either the President or Vice-president be unable to attend, either has power to appoint a deputy, in default of which the Vice-president shall appoint deputies.

4. The Vice-president should be made cognisant of all correspondence and business generally by the Secretary, and is to be regarded in every way as the President's deputy in Wellington. All business should be submitted to the Vice-president before meetings of the Board or the Standing Committee, and he shall have power to call for all documents, books, and statements in connection with the Institute's business.

5. The Vice-president shall have general oversight of the office, and sign important letters or letters to important people in the absence of the President.

The Committee considered the appointment of an Hon. Secretary unnecessary.

Fellowship: On the 8th June notification of the election of Dr D. Miller and Dr E. Kidson to the Fellowship of the New Zealand Institute was sent forward to be gazetted.

On the 21st September the incorporated societies were asked for nominations for the 1932 Fellowship election, and 12 nominations were received and submitted to the Fellows for selection.

The result of the selection was forwarded to members of the Board on the 9th March, and the election will take place at the Annual Meeting in May.

Hector Award: On the 27th May a letter was received from Dr W. P. Evans thanking the Institute for awarding him the Hector Medal, and stating that he appreciated the honour conferred on him.

At a meeting of the Wellington Philosophical Society held on the 25th June the medal and prize were presented to Dr Evans by Mr B. C. Aston, Vice-president of the New Zealand Institute, who made reference to the amount of research work, particularly into the chemistry of New Zealand brown coals, carried out by Dr Evans; he referred also to the influence exerted by Dr Evans on his students, many of whom were now occupying important positions in industry and education.

Hutton Grants: Two applications for Hutton Grants referred by last Annual Meeting to the Standing Committee were considered and were not approved.

Research Grants: Six applications for research grants were received during the year, but owing to the Government making no provision on the Estimates for research grants five of these applicants were informed that there was no money available. The sixth applicant, who was eligible under the Hutton Grant regulations, was informed that his application (if he desired it) would be considered at the Annual Meeting with other applications for Hutton Grants.

T. K. Sidey Summer Time Fund: The regulations approved by the Board of Governors were handed over to the Crown Law Office for drafting and for the necessary Declaration of Trust to be drawn up. Two additional regulations were included: one allowing a Fellow of the Institute to nominate a person to receive the award, subject to that person's consent to nomination, and one allowing the Institute to deduct reasonable administration expenses. The draft was approved, but subsequently a point was raised by Sir Thomas Sidey as to whether the terms of the Trust were wide enough.

A notice intimating that an award was to be made appeared in the press on the 17th July, 1931. The Award Committee, after considering the applications, referred the matter to the Standing Committee. At a meeting of the Standing Committee held on the 15th April, 1932, a sub-committee, consisting of Mr Aston, Hon. G. M. Thomson, and Mr Currie, law draughtsman, was set up to report to the Annual Meeting after conferring with Sir Thomas Sidey.

Hector Observatory: At the last Annual Meeting it was resolved that the Prime Minister be requested to have the name of the Dominion Observatory altered to Hector Observatory. In reply to this request the Prime Minister wrote stating that he would give the matter careful consideration.

Title "Royal": Acting on instructions from last Annual Meeting, application was made to the Hon. Minister of Internal Affairs for permission to use the prefix "Royal" in the title of the New Zealand Institute. A letter dated 5th April, 1932, has been received from the Hon. Minister stating that the application has been transmitted to his Excellency the Governor-General.

New Zealand Institute Act: A Committee was set up at last Annual Meeting to report on alterations required in the New Zealand Institute Act consequent upon the change of date of the Institute's year and Annual Meeting. The Committee reported as follows:—

1. That it is not necessary to make any alteration in Section 3 of the Act. (Date of appointment of members of the Board of Governors.)
2. That the following dates in the Regulations be advanced three months, that is to say:—

   Regulation 10 (a).—1st December to be altered to 1st March.

   Regulation 19.—30th November to be altered to 1st March.

   Research Grant:

   Regulation 2.—1st January to be altered to 1st April (two places).

   Hutton Regulations:

   Regulation 7.—30th September to be altered to 31st December.

   Regulation 9.—31st December to be altered to 31st March.
3. That the following dates in the Hamilton Fund Regulations be advanced six months, that is to say:—

   Regulation 5.—1st July to be altered to 1st January.

   Regulation 7.—30th June to be altered to 30th December.

London Agency: Arrangements had been made with the High Commissioner for his office to have the Institute's publications on sale without commission charges, but as he anticipated that very few sales would be effected from his office it was decided to allow Messrs Wheldon & Wesley, Ltd., who had expressed the desire to resume the agency, to do so on the usual terms, on the understanding that their outstanding account would be paid in full. Three instalments of this account have been received during the year, and a promise of a settlement of the balance at an early date.

Fifth Pacific Science Congress: A large amount of correspondence has been received in connection with the Fifth Pacific Science Congress, which was to have been held in June of this year in Canada. On the 2nd November a cable was received intimating that the Congress was postponed for a year, and a letter received on the 30th November confirmed the cable message as follows:—

> " . . . The Government of Canada, in consideration of the disturbed economic conditions prevailing throughout the world to-day, have decided that it would be inadvisable to proceed with the proposed meeting of the Fifth Pacific Science Congress in Canada in May and June, 1932, and observing that the Fourth Congress suggested that a longer inter-Congress period might be found advantageous in the future, have instructed the President and members of the Executive Council to arrange for the postponement of the Fifth Pacific Science Congress for one year, in the hope that happier times may then permit the holding of a successful and profitable meeting at which even the most distant countries will find it possible to be represented."

Members of the New Zealand Institute who were preparing papers for presentation at the Congress were accordingly advised of its postponement.

A preliminary programme of authors and papers has been received, and is available for reference by those interested.

Official delegates have not yet been appointed.

At last Annual Meeting the possibility of sending an invitation for the Sixth Pacific Science Congress to meet in New Zealand was left in the hands of a sub-committee. It has since been learned that the Sixth Congress is to be held in Siam, rendering action by the sub-committee unnecessary.

British Association for the Advancement of Science: 1931 being the centenary of the British Association, and instructions having been received from the last Annual Meeting to prepare a scroll containing the congratulations of the New Zealand Institute, an address was drawn up, and Professor Shelley very kindly undertook the engrossing of it. It was signed by the President, Professor Segar, and by his Excellency the Governor-General as a member of the Board of Governors.

Professor Sommerville, who represented the Institute at the celebrations in London, and who presented the address, wrote as follows: "The New Zealand Institute has done very handsomely in the matter of the address. It is a very beautiful piece of work, unique in form, I think, as the others are all scrolls in cylinders. It has provoked great admiration. I saw some of the Faraday addresses, but I don't think there were any so beautiful, though many of them were fine. There are very few British Association ones."

The New Zealand Institute is indebted to Professor Shelley for his work.

Concurrently with the opening of the British Association, meetings of the Wellington Philosophical Society and of the Standing Committee were held, and his Excellency the Governor-General having expressed the view that it would be appropriate if a cable could be despatched to the British Association, the following cable was sent through the Prime Minister's office:—"Meeting of New Zealand Institute held to-day, on motion of Governor-General, Lord Bledisloe, send hearty greetings to British Association Centenary meeting, and gratefully recognise the influence of the Association in the furthering of science in the Empire, and its advantage to the primary producers of New Zealand."

An extract from Professor Sommerville's report as the New Zealand Institute's representative at this meeting, as well as the Faraday and Clerk Maxwell celebrations, is attached. (See page XXVI.)

Reform of the Institute: Mr B. C. Aston read a report of a subcommittee set up by the Standing Committee to report on a scheme for augmenting the funds of the Institute.

REPORT OF THE COMMITTEE APPOINTED TO ADVISE ON A SELECTED PLAN FOR ENSURING AN IMMEDIATE AND SUPPLEMENTARY INCOME PAYABLE DIRECT TO THE NEW ZEALAND INSTITUTE.

The reduction of the statutory grant for management expenses, payable annually by Parliament to the New Zealand Institute, from £1500 to £750 was a blow to the Institute's finances, which called for immediate remedy as well as for future provision in order to provide for a workable credit balance for management expenses and publication costs. By transferring, with the consent of Parliament, cash in hand accruing from lapsed research grants amounting to £440 to the General Fund for publication expenses, the income from Government sources was increased from £750 to £1190, so that the position for the year ending 31st March, 1932, was fairly met. The outlook for the year ending 31st March, 1933, and subsequent years is, however, not so satisfactory. It is understood that the amount to be voted by Parliament for the current year will only be £500 instead of £750; also that by recent legislation, instead of the Institute's annual grant being payable by authority of the New Zealand Institute Act or Finance Act, this vote among others shall be subject to annual review.

At a meeting of the Standing Committee on 25th August, 1931, the idea of having a body of research workers and others interested contributing an annual subscription direct to the Treasurer of the New Zealand Institute was adopted as a skeleton scheme which was left to a sub-committee to elaborate.

It is proposed to form a new Society, one qualification of the members being that they shall be already members of the New Zealand Institute, that is, must belong to one of the incorporated Societies, the object of the Society to be the publication of scientific knowledge. Such a Society could claim to be admitted to incorporation with the New Zealand Institute if desired. One pound of each member's subscription should be paid to the Hon. Treasurer of the New Zealand Institute every year.

The Fellows of the New Zealand Institute would be eligible to join such a Society, and would no doubt provide a welcome nucleus for starting the Society. It has been suggested that one way of raising income would be to tax the Fellows to the extent of £2 2s subscription per annum, but this could not be done without their consent, since they were elected without imposing any extra fees.

It may be asked what subscribers are to get in return for their annual fee to this new Society, seeing that they are already members of the New Zealand Institute through belonging to one of the societies, and are thus entitled to all the benefits conferred by membership of the New Zealand Institute. A better question to ask is, however, what they will lose if the *Transactions* cease publication. In such an event the opportunity of publishing papers in a recognised New Zealand Journal which is filed for reference in every scientific library of importance in the world, and has been appearing regularly since 1868, would be lost, and New Zealand zoologists, geologists, and botanists would then lack a channel for publishing their results.

(Signed) H. B. KIRK.
B. C. ASTON.

Wellington,
May 17, 1932.

Some discussion took place regarding the proposals outlined in the report, and finally on the motion of Professor Speight, seconded by Mr Aston, it was resolved that the report be circulated to the incorporated societies and to every member of the Institute for consideration and report.

On the motion of Dr Farr, seconded by Professor Speight, it was resolved that the replies be collated and a further report prepared for next Annual Meeting.

DRAFT DEED T. K. SIDEY SUMMER TIME FUND.

TO ALL TO WHOM THESE PRESENTS SHALL COME THE NEW ZEALAND INSTITUTE (hereinafter called "the Institute"), a body politic and corporate under and by virtue of the New Zealand Institute Act, 1908, SENDS GREETING:

WHEREAS the sum of £500 has been collected in shilling subscriptions for the purpose of commemorating the passing by Parliament of the Summer Time Act, 1927, through the instrumentality of Sir Thomas Kay Sidey, Knight, Barrister, some time his Majesty's Attorney-General for New Zealand:

AND WHEREAS the said sum has been paid to the Institute for the purpose aforesaid and further sums may hereafter be received by the Institute for the same purpose:

AND WHEREAS it was intended that such commemoration should take the form of a public charitable purpose to be more particularly defined by the Institute and it is expedient that the precise terms on which the said moneys are held should be declared in manner hereinafter appearing:

NOW KNOW YE that the Institute doth hereby declare as follows:—

1. THE Institute does and will stand possessed of the said moneys and all other moneys hereafter received by it to be held under the trusts of these presents and the augmentation of such respective moneys upon the trusts following, that is to say:—

(*i.*) Upon trust to blend and convert the same into one Fund to be known as the "T. K. Sidey Summer Time Fund" (hereinafter referred to as "the Fund").

(*ii.*) Upon trust to invest the Fund or cause the Fund to be invested on behalf of the Institute by any corporation empowered to act as a Trustee in such investments as may from time to time be permitted to Trustees by the law for the time being in force with power in its discretion to vary such investments.

(*iii.*) Upon trust out of the income of the Fund in the first place to pay all costs and expenses of or incidental to the management of the Fund and the income thereof or the execution of any of the trusts or powers of these presents.

(*iv.*) Upon trust out of the income of the Fund from time to time to pay and transfer to the General Funds of the Institute in recompense for general administration expenses incurred in connection with the Fund such sums as the Institute may think reasonable:

Provided that the sums so paid and transferred in respect of any annual period apart from the costs and expenses paid in respect of that period pursuant to the foregoing paragraph (*iii.*) of this clause shall in no case exceed five per centum of the sum certified by the Auditor to be the income of the Fund for that annual period.

(*v.*) Upon trust during the lifetime of the last survivor of the issue now living of his Majesty King George the Fifth and for twenty-one years afterwards to invest one-tenth part of the sum certified by the Auditor to be the income of the Fund for every annual period by investing the same in augmentation and so as to become a part of the Fund.

(*vi.*) Subject as aforesaid upon trust to pay and apply the current income and any accumulations thereof not formally by resolution of the Board of Governors of the Institute converted into capital from time to time as may be directed by the Board of Governors in perpetuity for the advancement of learning in manner hereinafter appearing, that is to say the promotion and encouragement as hereinafter set out of scientific research in the study of light visible and invisible and other solar radiations in relation to human welfare:

PROVIDED ALWAYS that such scientific research shall not be deemed to be limited to research in medical science:

PROVIDED ALSO that the Institute may at any time in its discretion extend such scientific research so as to include the general study of radiations of every kind.

2. PENDING the disbursement thereof any current income shall be invested whether by blending with investments of capital or otherwise but unless appropriated as part of the capital of the Fund by resolution of the Board of Governors such current income so invested and the earnings thereof shall remain available for disbursement in manner provided by these presents.

3. THE Institute records a wish expressed by the said Sir Thomas Kay Sidey that after the expiration of the period during which accumulation is directed under the trusts hereinbefore declared the Institute should continue to set aside and invest one-tenth part of the annual income of the Fund and so far as lawfully may be or until otherwise lawfully directed should defer the application thereof for the purposes herein set out until by virtue of such setting aside and of the accumulation hereinbefore directed and other accretions to the Fund the annual income of the Fund represents interest derived from a capital sum of not less than Ten Thousand Pounds (£10,000) and the Institute declares its accord with and adherence to the said wish:

Provided always that nothing contained in this clause shall take effect otherwise than as a precatory declaration.

4. SUCH part of the income as the Institute may think proper but so that no prize be of a less value than One Hundred Pounds shall from time to time be paid and awarded as a prize to some person who has in the opinion of the Board of Governors made a valuable contribution or contributions to human knowledge by original scientific research in the study aforesaid:

PROVIDED ALWAYS that primarily and until the income of the Fund increases to an amount suitable for frequent awards of an international character an award shall be made to some person who was born in New Zealand or who has received the greater part of his or her education in New Zealand or to some person for research work which has been carried out in New Zealand, but it shall be in the discretion of the Board of Governors at any time to offer to make an award under circumstances not complying with any of the stipulations of this proviso.

5. THE Institute shall out of the Fund provide and present to every person to whom a prize is awarded a bronze medal bearing the name of the Fund and otherwise suitably inscribed:

PROVIDED ALWAYS that no such provision shall be made upon any occasion on which a similar medal shall be provided by the said Sir Thomas Kay Sidey or any member of his family:

PROVIDED ALSO that whenever possible the presentation of the medal accompanying the award shall take place upon some public occasion.

6. NOT more than one award shall be made to the same person.

7. THE Institute may in respect of any particular proposed award specify a particular branch of the subject-matter of the said research as that in respect of which such award is to be made.

8. IN making any award from the Fund the Board of Governors shall obtain the assistance as assessors of one or more persons skilled in the subject-matter of the research or may for that purpose nominate as assessor one or more of its own members so qualified and may from time to time make from the income of the Fund a reasonable payment to any person not being a member of the Board for his services as assessor and no award shall be made except on the recommendation of at least one person so appointed by the Board of Governors as assessor.

9. THE Board of Governors may refrain from making an award on any occasion on which it considers that no contribution to knowledge has been brought to its notice of sufficient merit to justify the honour.

10. (a.) The Board of Governors may from time to time make Regulations not repugnant to these presents providing for the administration of the Fund, the way in which a proposed award is to be notified, the procedure to be followed in making an award, or any other matters connected with these presents.

(b.) Any such Regulations may be amended revoked or replaced in the way in which for the time being the Rules and general Regulations of the Institute may be amended revoked or replaced.

(c.) Until amended revoked or replaced as aforesaid the Regulations hereinafter set out shall take effect as Regulations made under the powers hereby conferred.

11. (a.) The Institute shall cause to be published once or oftener as may be deemed convenient either with the Proceedings of the Institute or otherwise:

(*i.*) The terms of these presents excluding any part of the Regulations hereinafter set out theretofore revoked;

(*ii.*) The terms of any other Regulations made under the powers hereby conferred and for the time being in force;

(b.) The Institute shall cause to be published annually either with the Proceedings of the Institute or otherwise:

(*iii.*) A list of persons to whom awards from the Fund have been made;

(*iv.*) A statement of accounts duly audited showing the income and expenditure of the Fund for the annual period then last completed, a summary of cash receipts and disbursements during that period, and a balance sheet of the assets and liabilities of the Fund at the close of that period.

IN WITNESS whereof these presents have been executed this
day of 1932.

REGULATIONS.

(1.) The Board of Governors shall give not less than six months' previous public notice in not less than four of the principal newspapers circulating in New Zealand of its intention to consider the making of any award from the Fund and the date by which applications for the award are to be received.

(2.) Such notice shall specify the qualification of applicants as determined pursuant to Clause 4 of the foregoing Declaration of Trust, and also the subject-matter of the research either as set out in paragraph (*vi.*) of Clause 1 of the said Declaration of Trust, or as extended under the proviso to the said paragraph (*vi.*), or as limited under Clause 7 of the said Declaration of Trust according to any determination thereon of the Board of Governors.

(3.) Applicants for the award may submit either theses specially prepared for the award or copies of published works not specially so prepared, or both as the applicant may think fit.

(4.) The Board of Governors and its assessors will not be limited to consideration of theses so submitted, but may take into account any knowledge that they may have of the research of any applicant or person nominated.

(5.) A nomination of a person to receive the award may be made by any member of the Board or Fellow of the Institute, but no award shall be finally declared in favour of any person except on the personal application of such person, or if application has not been so made then until such person's concurrence in the proposed award has been received by the Institute.

THE COMMON SEAL OF THE
NEW ZEALAND INSTITUTE was
hereto affixed in the presence of

T. K. Sidey Summer Time Fund: The draft Declaration of Trust and the Regulations governing the T. K. Sidey Summer Time Fund were then considered, and a good deal of discussion took place regarding No. 5 of the Regulations. This clause was finally amended in accordance with a wish expressed by Sir Thomas Sidey as follows:

(5) "A nomination of a person to receive the award will be received from any member of the Board of Governors or Fellow of the Institute, but no award shall be finally declared in favour of any person until after his concurrence in the proposed award has been received by the Institute."

Sir Thomas Sidey at this stage attended the meeting, and was cordially welcomed by the Board. Sir Thomas, in thanking the Institute for the invitation extended to him to be present on the occasion of the final settlement of the terms of the Declaration of Trust, said he appreciated the free consultation regarding it which had been afforded to him by the Institute and by individual members of the Board. He stated that he wished the Institute to have as wide discretionary powers as possible in order that in future, if conditions changed and different points of view arose, they might be able to make such modifications as were found to be necessary. At the present time the general purpose of the award was for research in light radiation in regard to human welfare, but the Board had been given power to make it wider by applying it to radiations of every kind.

He referred to a possible further donation of £1000 to the Fund, and stated that he hoped that in time the Fund would reach the sum of £10,000. He was exceedingly grateful to the Institute for undertaking the administration of the Fund—he could think of no body which would administer the Fund so well.

He wished the Institute, in addition to deducting all actual expenses, to deduct 5 per cent. of the income for administration purposes. He considered this only reasonable. He reiterated his wish to make up any necessary balance so that the first award would be not less than £100, and when required he would remit a cheque for the amount.

Sir Thomas expressed his appreciation of the services of Mr Currie, Crown Solicitor, in drafting the Declaration of Trust and in giving his advice on several points.

He also made reference to Mr Hudson's paper in the *Transactions* proposing a scheme of daylight saving, and which anticipated that of Willett, of England. He paid a tribute to Mr Hudson's foresight, and stated that he had frequently made use of his arguments in the House.

Finally Sir Thomas stated that he considered himself fortunate to have seen such a memorial in existence, and he was anxious to see the first award made.

He was not without hope that the original whole hour would be reverted to. The chief opposition to it came from the dairy farmer, but the dairy industry, according to statistics, did not suffer during the year when the hour was in force.

Dr C. Coleridge Farr stated that the Board of Governors was very grateful to Sir Thomas Sidey for addressing them as he had done. He had expressed his views regarding the Fund very clearly, and his remarks would greatly assist the Institute in administering the Fund. He trusted that Sir Thomas's address would be placed on record in the Minutes and published in the press.

Mr M. A. Eliott, seconded by Professor Easterfield, moved the following resolution:—" That the Board of Governors request the Government to introduce legislation to bring the half-hour Daylight Saving Act to include the whole twelve months."

In speaking to the resolution Sir Thomas stated that there was more involved in the resolution than appeared on the surface. He drew attention to the fact that New Zealand was so situated that there was a tremendous difference in the time by the sun between the North Island and the southern portion of the South Island, and that to enforce daylight saving in winter would result in considerable inconvenience and dislocation of services in the latter.

In view of the remarks of Sir Thomas Sidey, the mover of the resolution was given leave to withdraw his motion.

The following resolutions were then carried:—

1. That the Institute accept the Trust of the T. K. Sidey Summer Time Fund.
2. That in respect of the first award from the Fund the notifications heretofore directed to be given and the appointment of assessors be accepted as sufficient and confirmed, and that an award be made accordingly.
3. That to provide for the future administration of the Fund the Institute adopt a Declaration of Trust in terms of the draft deed now submitted to the meeting, and that the Common Seal of the Institute be affixed accordingly to an engrossment to be prepared in the words of the draft.
4. That subject to any steps already taken in respect of the first award and confirmed by this resolution, and any steps still to be taken and dependent on steps already taken, the terms of the said Declaration of Trust shall also govern the first award from the Fund.

On the motion of Professor Easterfield it was resolved that the President sign the Declaration of Trust as it had been amended that morning.

Professor Segar then cordially thanked Sir Thomas Sidey for his attendance, and Sir Thomas withdrew.

Consideration of matters arising out of the Standing Committee's Report was then resumed.

Endowment Fund: The Vice-president pointed out the desirability of having a Declaration of Trust drawn up which gave the Institute power to use only the annual interest of the Fund in any year. He mentioned that the Crown Solicitor, Mr Currie, would draw up the Deed. It was resolved to authorise this to be done.

International Research Council: It was reported that the Department of Scientific and Industrial Research would not again pay the Institute's subscription to the International Research Council, and on the motion of Dr Kidson it was resolved that the Institute pay the subscription of 100 gold francs.

HONORARY TREASURER'S REPORT.

The Balance Sheet for the 12 months ending 31st March shows a balance of Assets over Liabilities of £799 15s 3d, against which there are commitments for printing *Transactions*, Volume 62, Part 3/4, amounting to £141 7s 5d.

The improved position as compared with the last Balance Sheet has been occasioned by the transfer (by special vote of Parliament) of the Research Grant Fund of £440 to the General Fund for publishing.

The old balance due to the Government Printer has at last been finally liquidated by a payment of £148 15s 11d.

Since my last report the statutory grant has been further reduced from £750 to £400, (although possibly this may be increased to £500). This drastic reduction in our income, i.e., from £1500 to £400, has caused the greatest concern to the Finance Committee, and has necessitated material cuts in salaries and costs of printing. The size of Volume 62 has been reduced considerably, and Volume 63 will also have to be issued in a very much abbreviated form.

The Trust Accounts are in a satisfactory condition, although the reduction in rates of interest which has now become law will reduce the income from investments in future. The Carter Bequest Capital Account is growing at the rate of about £400 per annum.

I have once again to state that the books and accounts have been kept in an excellent manner by the Secretary.

M. A. ELIOTT, Hon. Treasurer.

NEW ZEALAND INSTITUTE.

Statement of Receipts and Expenditure for Year ending 31st March, 1932.

Receipts.

	£	s.	d.
Balance at 31st March, 1931	1,157	0	10
Statutory Grant	750	0	0
Levy Volume 61 (balance)	165	18	0
Levy Volume 62	203	10	0
Transfer Research Grant Fund to General Fund	440	0	0
Contributions towards Publications Expenses	22	7	9
Research Grants from Treasury	105	2	0
Research Grants Refunded	34	2	10
Interest Post Office Savings Bank	23	5	6
Sales of Publications	113	19	0
Carter Bequest Interest	483	18	11
[illegible] Memorial Fund „	72	0	3
Hutton Memorial Fund „	79	16	11
Carter Library Legacy „	9	17	0
Hamilton Memorial Fund „	2	8	10
Sidey Summer Time Fund „	30	13	6
Endowment Fund „	37	16	11
Trust Funds transferred to Bank of New Zealand	435	9	0
Favourable Exchange London Drafts	3	5	10
	£4,171	2	1

Expenditure.

	£	s.	d.
Ferguson & Osborn, Vol. 61 (3/4), 62 (1)	314	12	11
Otago Daily Times, Vol. 62 (2)	107	3	10
Government Printer—Balance of Account	148	15	11
Stationery	1	12	11
Transfer Research Grant Fund to General Fund	440	0	0
Transactions Purchased	3	0	0
Travelling Expenses	4	8	6
Salary	270	0	0
Research Grants Instalments	249	15	8
Petty Cash	16	6	3
Charges (Insurance, Bank, Audit, etc.)	6	4	11
A. G. Wyon (Summer Time Medal)	127	7	7
Trust Funds Invested	348	3	11
Hector Award	60	0	0
Trust Funds Audit Charges	5	4	0
Interest credited direct to Trust Accounts	678	15	5
Balance as under	1,389	10	3
	£4,171	2	1

	£	s.	d.	£	s.	d.
Bank of New Zealand	221	9	5			
Post Office Savings Bank	1,166	16	6			
Petty Cash in Hand	1	4	4			
				1,389	10	3
				£1,389	10	3

M. A. Eliott, Hon. Treasurer.

The Audit Office having examined the Balance Sheet and accompanying Accounts required by law to be audited, hereby certifies them to be correct subject to the exception of expenditure of £1. 1s and 5s 3d on a wreath and scroll respectively, which is without authority of law.

(Signed) G. F. C. Campbell, Controller and Auditor-general.

NEW ZEALAND INSTITUTE.

Statement of Liabilities and Assets as at 31st March, 1932.

Liabilities.

		£	s.	d.
Carter Bequest	Capital Account	8,504	17	7
Hector Memorial Fund	„ „	1,184	18	1
Hutton Memorial Fund	„ „	1,314	8	6
Hamilton Memorial Fund	„ „	58	19	6
Carter Library Legacy	„ „	100	0	0
Summer Time Fund	„ „	500	2	6
Endowment Fund	„ „	748	2	0
Carter Bequest	Revenue Account	266	11	7
Hector Memorial Fund	„ „	118	18	6
Hutton Memorial Fund	„ „	249	3	5
Hamilton Memorial Fund	„ „	5	0	3
Carter Library Legacy	„ „	58	12	6
Summer Time Fund	„ „	49	8	11
Endowment Fund	„ „	176	3	11
Library Fund		170	19	4
Research Grants Fund		256	11	1
Travelling Expenses—Institute's share of pooling		15	13	3
C. M. Banks, Ltd.—Stationery		1	2	6
Balance of Assets over Liabilities		790	15	3
		£14,585	8	8

Assets.

		£	s.	d.
Inscribed Stock		10,217	1	10
Post Office Inscribed Stock		2,135	6	10
Bank of New Zealand		221	9	5
Post Office Savings Bank		1,166	16	6
Petty Cash in Hand		1	4	4
Outstanding Accounts		27	3	7
Carter Bequest	Account P.O.S.B.	269	6	7
Hector Memorial Fund	„ „	121	0	6
Hutton Memorial Fund	„ „	251	5	5
Hamilton Memorial Fund	„ „	64	7	3
Carter Library Legacy	„ „	50	2	6
Summer Time Fund	„ „	51	3	11
		£14,585	8	8
By Balance		£790	15	3

New Zealand Institute Trust Accounts.

Carter Bequest for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Interest Invested	248	1	5	By Balance	33	9	1
„ Administration Expenses	2	15	0	„ Interest	483	1	5
„ Balance	266	11	7	„ Books Sold	0	17	6
	£517	8	0		£517	8	0
				By Balance	£266	11	7

Hector Memorial Fund for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	2	2	0	By Balance	109	12	9
„ Engraving Medal ..	0	12	6	„ Interest	72	0	3
„ Hector Award	60	0	0				
„ Balance	118	18	6				
	£181	13	0		£181	13	0
				By Balance	£118	18	6

Hutton Memorial Fund for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	2	2	0	By Balance	171	8	6
„ Balance	249	3	5	„ Interest	79	16	11
	£251	5	5		£251	5	5
				By Balance	£249	3	5

Hamilton Memorial Fund for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	0	7	6	By Balance	4	3	4
„ Half Interest to Capital Account	1	4	5	„ Interest	2	8	10
„ Balance	5	0	3				
	£6	12	2		£6	12	2
				By Balance	£5	0	3

T. K. Sidey Summer Time Fund for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To A. G. Wyon for Medal	123	16	5	By Balance	147	18	0
„ Customs for Medal ..	3	11	2	„ Interest	30	13	6
„ Administration Expenses	1	15	0				
„ Balance	49	8	11				
	£178	11	6		£178	11	6
				By Balance	£49	8	11

Endowment Fund for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Interest Invested ..	100	2	6	By Balance	103	0	0
„ Administration Expenses	1	15	0	„ Interest	61	2	5
„ Balance	176	3	11	„ Sales of Publications	113	10	0
	£278	1	5		£278	1	5
				By Balance	£176	3	11

Carter Library Legacy for the Year ending 31st March, 1932.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	0	10	0	By Balance	49	5	6
„ Balance	58	12	6	„ Interest	9	17	0
	££59	2	6		£59	2	6
				By Balance	£58	12	6

Carter Library Legacy—Copy of Public Trustee's Account.

	£	s.	d.		£	s.	d.
Residuary Capital Account	50	0	0	Residuary Income Account—Interest 31st December, 1930, to 31st December, 1931, at 5¼ per cent. ..	2	12	6
	£50	0	0		£2	12	6

The Hon. Treasurer read his report and moved the adoption of the Balance Sheets and Trust Accounts Statements, which had been duly audited by the Auditor-general. Carried.

REPORT OF THE HONORARY EDITOR.

The new printers of the *Transactions*, the *Otago Daily Times*, have now completed satisfactorily Volume 62. This volume, consisting of 271 pages and 41 plates, is necessarily very much smaller than recent volumes, but it is a matter of congratulation to be able to publish at all, with a Government grant so sadly reduced. Matter is in hand for Volume 63, and it is hoped that funds may be sufficient to make this volume equal to its predecessor.

During the absence of the Hon. Editor in England the duties were undertaken and carried out with great care by the Hon. G. M. Thomson. The Institute is under a deep debt of gratitude to him for giving up so much of his valuable time to this somewhat arduous work.

D. M. Y. Sommerville, Hon. Editor.

The report of the Hon. Editor was read by Professor Sommerville and adopted.

REPORT OF THE HONORARY LIBRARIAN.

The condition of congestedness in the Library continues to grow more acute, and it will be necessary in order to make space to stow away some of the sets of periodicals which are less often consulted. When funds become again available there is a great deal of binding which is urgently required. This is apt to be postponed until it is too late and the sets of periodicals have become defective.

The death of Dr H. T. Ferrar is a great loss, for besides taking a keen general interest in the Library he presented the Library for many years with his copy of the report of the British Association, of which he was a Life Member.

D. M. Y. SOMMERVILLE, Hon. Librarian.

The adoption of the Hon. Librarian's report also was moved by Professor Sommerville and carried.

On the motion of Mr G. M. Thomson, seconded by Professor Speight, Professor Sommerville was cordially thanked for his arduous work as Hon. Editor.

RESEARCH GRANTS REPORT.

Mr G. Archey in 1926 was granted £40 for a research on New Zealand Chilopoda. On the 6th April, 1932, he reported that it was expected that the report would have been completed during the year, but it has been delayed through the loss in the return post of specimens sent to England for comparison with types. Further specimens have had to be sent; meanwhile collecting has been carried out in the North Cape, Kaipara, Waitakeri, Waikato, Bay of Plenty, and Urewera districts, and a considerable amount of new material secured. Expenses incurred amounted to £4 9s, leaving in hand a balance of 17s 4d.

Mr B. C. Aston in 1928 took over from Dr Malcolm £9 16s 7d for a research on pukatea bark. He reported on the 19th April that the paper on the constitution of Pukateine has been published by one of Professor Barger's students, and the syntheses of the two alkaloids of the bark have been published. A request has been received for more material, and this was procured through the kindness of the Forestry Department. This is the first occasion that a crystalline product of the New Zealand flora has been synthesised, and Mr Aston considers it extremely fortunate that such an eminent plant research chemist as Professor Barger has become interested in the chemistry of our unique flora. Dr Fogg, Demonstrator in the Otago Medical School, has reported on his experiment with pukateine hydrochloride on animals to determine its action on the heart. His work included observation of the effect on intravenous injection, electro cardiographic and perfusion experiments. There is an unexpended balance of £6 8s 1d.

Professor W. N. Benson in 1925 was granted £50 for preparing rock sections of the Dunedin regions. He reported on the 10th March that the whole of the grant had been expended. The work in the fields is nearing completion, but laboratory work is still incomplete.

Professor W. N. Benson in 1930 was granted £150 for an expedition to Preservation Inlet. He reported on the 10th March that the writing up of the work of this expedition has gone rapidly ahead during the last vacation, and three-fifths of the work is almost ready for publication. He hopes to present three portions of the work during this session, and to complete the remainder during next vacation. The laboratory study of the material collected has proved even more interesting than had been gathered from the field observations, so that his collaborator and he hope that the results will be a useful contribution to New Zealand science.

Mr A. E. Brookes in 1927 was granted £40 for the study of Coleoptera of the islands off the coast of Auckland. He reported on the 4th April that during the summer an investigation was carried out on Little Barrier Island,

and a good deal of material secured, but owing to the extremely dry conditions and the presence of a large number of insectivorous birds the number of specimens collected was perhaps not so large as it might have been under normal conditions. Hen Island, an uninhabited island off Whangarei Heads, was also visited, and seven days were spent in collecting there, and some interesting material secured. Several hundred specimens from these localities have now been mounted, and the remaining work will probably occupy another twelve months. Expenditure for the year amounted to £14 7s 10d, and there is an unexpended balance of £1 16s.

Mr J. W. Calder in 1930 was granted £30 for research in the vegetation of Arthur's Pass. He reported on the 29th March that the investigation of regeneration of sub-alpine scrub after burning had been continued during the year, and a detailed examination made of the area described by Dr Cockayne in a paper in the *Transactions* of 1899 and numerous photographs taken, many of them of areas photographed by Dr Cockayne 34 years ago, and thus furnishing an invaluable record of the changes which have taken place in the vegetation during that period. A paper describing the main changes has been accepted for publication in the Journal of Ecology. The work is being continued and permanent quadrants located. Expenditure amounting to £24 17s 2d has been incurred.

Miss L. Cranwell in 1930 was granted £20 for research on marine algae of the West Coast near Auckland, and she reported on the 6th April that the survey is still incomplete, and it is unlikely that there will be anything ready for publication before the end of the two years' period which was suggested as the minimum for the work. Collecting and observation work have been undertaken along the coast. Special attention has been given to periodicity, and sufficient time has now elapsed to indicate striking seasonable changes. Miss Cranwell acknowledges generous assistance from Mr R. M. Laing, as well as of other overseas workers, in the identification of species. Expenditure amounted to £2 2s.

Dr G. H. Cunningham in 1928 was granted £25 for a mycological survey of Tongariro National Park. He reported on the 23rd March that the Park had been visited on four occasions. An investigation was made of a disease of Pinus spp. which had become widely spread through certain afforested areas in Karioi, on the southern slopes of Mount Ruapehu. Collecting was also done in this locality, and other collecting tours were undertaken. In all 16 additional species of fungi were added to previous collections. He has had great difficulty in identifying several of these collections, since many belong to groups with which he is not familiar, and little accurate aid can be secured by sending material abroad owing to the penchant of overseas workers to consider (too often without justification) most species from a foreign region as being undescribed. No expenditure was incurred in connection with these collecting tours.

Professor Florance in 1928 was granted £38 and in 1929 an additional £20 for research on oscillation crystals and supersonic waves. He reported on 4th April that during the last year work was carried out in an investigation of the fundamental modes of vibration of crystals, particularly with a view to correlating results obtained by various experimental methods (powder method, interference method, polarised light method). This investigation has not yet been completed. An investigation also was made of the sound field round oscillating crystals. The work was the subject of an honours thesis. The whole of the grant has been expended.

Mr F. W. Foster, who in 1921 was granted £25 to correlate the late Sir David Hutchins's notes, has now completed the work, and a substantial MS. is in the hands of the Institute. Part II, comprising three sections—Forest Policy, Introduced Conifers, Cold Country Eucalypts—has just been received. No decision has been arrived at regarding its publication. The whole of the grant has now been paid to Mr Foster.

Dr O. H. Frankel was in 1929 granted £32 12s and in 1930 an additional £20 for research on the cytology of New Zealand plants. He reported on the 3rd April that the research has progressed satisfactorily. A large number of fixations were carried out, and sections made on most of last year's material. Collections of live material were made for future cytological examination. Expenditure during the year amounted to £5 19s 11d.

Miss Heine was in 1930 granted £15 for research in the pollination of New Zealand plants. She reported on the 16th March that she had undertaken two expeditions to Mount Holdsworth and one to the Waihao Gorge to enable her to study the pollination of the plants in their natural surroundings. Besides these two expeditions she has visited Kapiti, Mount Hector, and Mount Monganui at her own expense with the idea of comparing the results with those obtained at Wilton's Bush and other local bush areas. During the year 119 species of plants included in 35 genera have been examined, and the frequency and efficiency of the different species of insects visiting have been noted, and several hundreds of insects collected and examined to determine the quantity and kinds of pollen found on them. The whole of the grant has been expended.

Dr Inglis from 1923-1930 was granted £125 for research on the essential oils of native plants. He reported on 31st March that work on totara and white pine was continued throughout the year. Further work on the oils of black pine and cedar was undertaken and completed. A small quantity of *Phyllocladus Alpinus* was also investigated. It was found that a crystalline diterpene was present in the leaves of several of the New Zealand trees, the most convenient source being *Dacrydium biforme*. Work on this is being continued, and reports of the completed researches are being prepared. There is an unexpended balance of £4 10s 5d.

Mr R. M. Laing in 1924 and 1929 was granted £125 for research on New Zealand Algae. He reported on the 18th March that the second part of the investigation on New Zealand species of Gigartina appeared in Volume 62 (2) *Transactions* New Zealand Institute, and the third part is in course of preparation. The whole of the grant has been expended.

Mr A. W. B. Powell in 1925 was granted £50 for an investigation of the molluscan fauna of Manukau Harbour. He reported on 15th March that further field work has been carried out. The microscope purchased by means of the grant has proved useful in the preparation of several papers. Expenditure amounted to £45 4s 1d.

Research Committee of Auckland Institute in 1925 was granted £65 for an ecological survey of the Waitemata Harbour. Through Mr Powell it reported on the 15th March that during the year a number of additional dredging stations had been established, and extensive notes of the ecology and percentage of organisms have been made. A paper is ready for publication, and special reports are being obtained on the seaweeds and bryozoa. The expenditure has amounted to £53 19s 11d.

Dr W. F. Short from 1925-1929 was granted £189 for investigation in the constitution of several constituents of New Zealand essential oils. He reported on the 28th March that a synthesis of the hitherto unknown 4-Methylphenanthrene has been effected, and the synthetic hydrocarbon compared with that obtained by selenium dehydrogenation of podocarpic acid. This synthesis was published in the Journal of the Chemical Society. Considerable progress has been made in the investigation of podocarpic acid, which has now reached such a stage that a provisional structural formula may be advanced. A lengthy paper is in course of preparation. The whole of the grant has been expended.

Professor R. Speight in 1928 was granted £50 for a geological examination of Mount Somers district. He reported on the 1st April that the field work has been practically completed and the report written. Special reports on the Brachiopods and the Foraminifera being prepared by Dr R. S. Allan and Mr Chapman and on the Bryozoa by Dr Uttley should be available soon. Professor Speight has prepared a geological map, but before it can be reproduced it will have to be redrawn, and he does not wish to go to any expense unless there is a chance of it and his report of about 75,000 words with photographs, maps, sections, etc., being published. It aims at giving a comprehensive account of the geology of the district, and more especially of the volcanic and tertiary beds. There is an unexpended balance of £10 14s 8d.

Dr G. H. Uttley in 1928 was granted £35 for micrographic apparatus for research on Bryozoa. He reported on the 1st April that he is continuing the work, and he hopes to get some papers published this year.

Professor F. P. Worley in 1923-25 was granted £50 for research on the chemistry of essential oils. He reported on the 24th March that during the year there had been no expenditure of the grant.

The Research Grants Report was adopted.

TONGARIRO NATIONAL PARK.

REPORT OF NEW ZEALAND INSTITUTE'S REPRESENTATIVE ON PARK BOARD.

Control of Chateau: By the Reserves and Other Lands Disposal Act, 1931, Section 19, the management of the Chateau was vested in the Department of Industries and Commerce, Tourist and Publicity, which assumed control of the Chateau and outlying huts, together with the areas formerly leased to the Tongariro Park Tourist Company, Ltd., on 11th November, 1931.

Park Improvements: A mountain hut at the 5800 feet level has been erected on Scoria Flat, Ruapehu, the £100 left by the late Mr William Salt, a member of the Board, being used in this work. The route from the Chateau to the Ohakune mountain-hut is being made conspicuous by poles in those parts liable to become obliterated by snow. The mountain disaster to a large party of Auckland University students in August, 1931, drew public attention to the dangers to be guarded against when adverse weather conditions are encountered by parties on the high levels, and a number of suggestions are now under consideration to guard against similar happenings.

Camping Facilities: An area containing five acres has been set apart at Whakapapa for the purposes of a camping ground, and is being brought under the Tourist and Health Resorts Act Control, 1908.

Meetings: During the year five meetings of the full Board of the Wellington Executive Committee were held, one at the Chateau. All of these meetings were attended by your representative.

Personnel of Board: Mr J. B. Thomson, C.B.E., late Chairman, retired on ceasing to hold the office of Under-secretary for Lands, but was re-appointed to the vacancy caused by the resignation of Mr F. F. Hockly. Mr E. Phillips Turner retired from the Board on ceasing to hold the position of Director of Forestry, being succeeded by Mr A. D. McGavock. Mr W. Robertson, Under-secretary for Lands, who has had long experience in every branch of the Lands Department, has been appointed Chairman of the Board in succession to Mr J. B. Thomson.

B. C. ASTON, Representative New Zealand Institute.

The report of the representative on the Tongariro National Park Board was presented by Mr Aston. He mentioned that the Board has received an application from a man for permission to cut dead firewood in an area in the Park. On the motion of Dr Cockayne, seconded by Mr Hudson, it was resolved that Mr Aston be instructed to oppose the granting of applications to cut dead or live timber in the area mentioned. Mr Oliver asked whether in the formation of the golf links at the Chateau the Board was permitting the destruction of the plant life round the Chateau. Mr Aston explained that the links were being formed in the area which had been leased by the Board to the company which erected the Chateau as part of the grounds on which the building stands. These grounds are now part of the area administered by the Tourist Department, which has now taken over the Chateau.

BOARD OF TRUSTEES NATIONAL ART GALLERY AND DOMINION MUSEUM.

REPORT BY VICE-PRESIDENT.

Since my last report four meetings of the Board have been held, all of which were attended by two representatives, the Vice-president and Professor Kirk, or by Dr Marshall, of the New Zealand Institute, and Mr Oliver, Director of the Dominion Museum.

The Carillon Tower contract was completed and the bells hung. The dedication service and opening were held on Anzac Day, 25th April, 1932. The building stone used was the vitric tuff from Putaruru, advocated by Dr Marshall. This stone appears to give general satisfaction, and may set an example for other designers of public buildings to follow.

On the resolution of the writer of this report a Planting Committee has been set up, and it is hoped that the trees planted in the Museum grounds will be wholly those of New Zealand, as this appears to be a unique opportunity for demonstrating the effectiveness of purely New Zealand materials, whether of building stone or decorative trees.

B. C. ASTON, Vice-president.

The Vice-president, who is a member of the Board of Trustees, moved the adoption of the report, which was carried. Mr Oliver made a further statement regarding the possibility of the building of the Dominion Museum and National Art Gallery being commenced at an early date.

REPORT OF THE NEW ZEALAND INSTITUTE'S REPRESENTATIVE ON THE NEW ZEALAND INSTITUTE OF HORTICULTURE.

The Institute continues to do a large amount of useful work. Monthly meetings of the Executive Council have been held in Wellington throughout the year ending 31st March, 1931. Your representative attended most of these meetings, at which many subjects received attention, among these being daffodil nomenclature, representation of the Institute at international and other conferences and organisation of conferences in New Zealand, citrus research, conduct of National Flower Shows, wireless lectures on horticultural subjects, bringing visiting horticulturists into contact with their fellows in New Zealand, education of gardeners, and the granting of diplomas, etc., to these and to florists and seedsmen, plant recording, bud selection, control of grass grub, judging rules, plant registration and patenting, election of Fellows and members of the Institute, the holding of popular lectures, the protection of native flora, etc.

This young Institute is at present passing through a trying time owing to the falling off of income and subscriptions due to the general depression. Pains are being taken by the Executive to cut down expenses, and the expenditure of the Journal of the Institute has been greatly reduced, as well as other expenditure. The annual subscription to this most praiseworthy Institute is only 12s 6d, and this includes subscription to the Journal. It should be supported by all gardeners, amateur and professional.

B. C. ASTON.

Mr Aston, representative on the Institute of Horticulture, moved the adoption of this report. Carried.

REPORT OF NEW ZEALAND INSTITUTE'S REPRESENTATIVE ON GREAT BARRIER REEF COMMITTEE.

Three meetings of the Committee were held during the year 1931.

Volume 3 of the "Reports of the Great Barrier Reef Committee" was published during the year. The scientific results of the British Expedition to the Great Barrier Reef are being published by the British Museum. The economic reports are to be published in Australia. An account of the Expedition by the leader, Dr Yonge, entitled "A Year on the Great Barrier Reef," has been published. Various articles on the Great Barrier Reef have been contributed to scientific journals by Dr Yonge, and a map of Low Island by Mr M. A. Spender has appeared in the Journal of the Royal Geographical Society.

The Government Analyst arranged for Messrs V. Cundith and F. Connah to complete the analyses of the bore on Michaelmas Cay. The results showed practically no increases in magnesium content from top to bottom.

W. R. B. Oliver,

New Zealand Institute Representative on the Committee.

Mr Oliver, representative on the Committee, moved the adoption of the report, which was carried.

Report of Professor D. M. Y. Sommerville, Delegate of the New Zealand Institute to the Faraday Centenary Celebrations (London, September 21-25), the British Association Centenary Meeting (London, September 23-30), and the Clerk Maxwell Centenary Celebration (Cambridge. October 1-2, 1931).

The occurrence together of these three centenary celebrations was a unique event in the scientific world, and, although of special significance to Great Britain, was given a highly international character by the attendance of distinguished representatives of physical science from all countries of the world. Never before, perhaps, have there been gathered together in one place and for one object so many stars of the first magnitude. Popular interest also amounted almost to enthusiasm, and was stimulated and fed by popular lectures, in hall and broadcast, by the very remarkable Faraday Exhibition in the Albert Hall, by the Shipping, Engineering, and Machinery Exhibition at Olympia, by numerous and varied excursions and visits to places of interest, and—although arranged for another purpose in connection with the International Illuminating Congress—by spectacular displays of flood lighting of the principal buildings in London, in itself a magnificent demonstration of results which have followed from Michael Faraday's celebrated discovery on August 29, 1831, of the generation of an electric current from magnets.

The Faraday Celebrations, organised by the Royal Institution of Great Britain in conjunction with the Institution of Electrical Engineers, opened on the afternoon of Monday, September 21, in the Lecture Theatre of the Royal Institution, where Faraday himself had lectured. The President, Lord Eustace Percy, welcomed the delegates—about 300 in number. Each delegate, as his name was read out, stood in his place and bowed to the President. At the same time his name was flashed on the screen, together with a picture of the town or institution which he represented. At the close of the meeting the delegates signed the roll, and an opportunity was given to inspect the illuminated addresses which many of the institutions had presented. There was no public presentation of addresses at any of the celebrations, and the majority of the delegates did not present any. There were, however, several fine works of art; but of those presented to the British Association there was none finer than the one presented by the New Zealand Institute.

The Faraday Commemorative Meeting was held on Monday evening in the Queen's Hall, when addresses were given by the Prime Minister, Lord Rutherford, Marchese Marconi, le duc de Broglie, Professors Elihu Thomson, P. Zeeman, and P. Debye. A letter was read from Einstein, whose absence from the meetings was greatly regretted. The Commemorative Address was delivered by Sir William Bragg, Faraday's successor at the Royal Institution, and a concluding address by the President, Lord Eustace Percy. The great gathering was entertained also by the Symphony Orchestra of the British Broadcasting Corporation, conducted by Sir Henry Wood. The proceedings of the Faraday Celebration were continued on Tuesday morning in the Kingsway Hall, where a conference was held on "The Place of Electricity in the Production and Utilisation of Power, and in Transport, Communications, and the Household." The speakers included the President of the Institution of Electrical Engineers (Mr Clifford C. Paterson), Mr J. S. Highfield, Sir Josiah Stamp, Miss C. Haslett (Electrical Association for Women), Mr L. B. Atkinson, and Sir Oliver Lodge. In the evening there was a conversazione at the Royal Institution, at which Sir William Bragg repeated some of Faraday's experiments.

On Wednesday afternoon, September 23, in the Royal Albert Hall, the British Association opened its meetings with the installation of the President, General Smuts. The hall was the scene of the Faraday Exhibition, and only the official delegates could be accommodated on the floor space. These delegates, who numbered about 400, were representatives of Universities, scientific societies, and the cities which had entertained the Association during its history. Each delegate, as his name was called, filed past the President, and received from him a cordial welcome. In the address which followed, General Smuts was historical, and in recalling the black prospects of 100 years ago showed himself a confirmed optimist, for, said he, "The situation was not really so black as it was painted; it never is." After a short interval the Albert Hall was occupied for a second ceremony, the official opening of the Faraday Exhibition. Mr C. C. Paterson presided, and the opening ceremony was performed by General Smuts. A vote of thanks was proposed by Colonel R. E. Crompton, one of the oldest members of the electrical industry, and a message of greeting from Dr F. B. Jewett, President of the Bell Telephone Laboratories, was emitted by wireless telephone from New York.

It would be impossible to describe briefly even the main features of the wonderful exhibition collected together in memory of Michael Faraday—the catalogue is a book of about 250 pages—but an idea may be given of the general impression presented by the great oval hall. In the centre stood a replica of the statue of Faraday which is in the possession of the Royal Institution, and radiating from it were eight sectors divided by alleyways. These terminated in illuminated arches, and were separated from the wall-stands by an alleyway extending all round the hall. The ceiling was covered with a velarium of white and yellow sectors, which was flood-lighted from below. A great yellow central lantern in the shape of three telescoping cylinders, 40 feet in depth, was suspended from the centre, while smaller half-lanterns of similar form surmounted the gallery pillars. All the lighting was indirect, and gave the impression of bright sunlight. The power used was about 250 kilowatts.

On Wednesday evening the Presidential Address on "The Scientific World-Picture of the Day" was delivered by General Smuts in the Central Hall, Westminster, to an audience of about 3000. As the number of members for the London meeting exceeded 5000 the address was relayed to other halls as well. At all the great meetings amplifiers were freely used, and the effect was occasionally disconcerting, as the sound could be heard proceeding from different directions and not simultaneously. But without the amplifiers the voice would have been inaudible in many parts of the hall.

During the following week, till Wednesday, September 30, the British Association, following the usual procedure, held sectional meetings in the mornings, organised innumerable excursions in the afternoons, and arranged public lectures and receptions in the evenings. To cater for 5000 members was a gigantic task, but the arrangements were in every respect admirable, and the huge reception rooms in the University of London were amply adequate. For a single individual it was possible only to sample the rich entertainment offered. Duty was performed in attending one Committee meeting and four meetings of Section A and its sub-sections, Pure Mathematics and Astronomy. The Presidential Address of Sir J. J. Thomson, whom Sir Oliver Lodge described as "the Master of Trinity, the Master of Physics," was listened to with interest. A small contribution by your delegate, referred to in the luncheon edition of the Evening Standard under the heading "More Secrets of Science Buried in a Welter of Strange Words," was communicated to Section A. An attempt was made to hear Niels Bohr on "Atomic Stability," but there was not even standing room. One of the great events was a discussion on "The Evolution of the Universe," which was listened to for three hours with breathless interest by several thousand people in the Central Hall, Westminster. Sir Frank Dyson presided, and the platform of speakers included almost the whole galaxy of original thinkers on this immense subject:—Jeans, E. A. Milne, de Sitter, Eddington, Millikan, Smuts, Dr Barnes (Bishop of Birmingham), Abbé Lemaître, and Sir Oliver Lodge. They all contradicted one another, and afforded an intense intellectual entertainment. Among the social functions which your delegate attended may be mentioned:—A Royal Society conversazione at Burlington House, a lunch at Olympia under the chairmanship of Professor Hele-Shaw, reception and graduation ceremony at the University, and an afternoon reception at the Forum Club. The Faraday delegates were entertained specially to a brilliant banquet by His Majesty's Government at the Dorchester Hotel, Park Lane, at which there were present about 300 guests. The financial crisis prevented the Prime Minister from being present, and his place was taken by the Marquis of Reading. On the same evening the wives of the delegates were entertained to dinner at the Forum Club. The hospitality offered to the delegates was indeed regal, and included, for example, temporary membership of the Athenæum and the Royal Automobile Club.

Among the purely business transactions of the British Association may be mentioned the announcement by the General Treasurer that, because of the present stringent conditions, an invitation from Lord Bledisloe for a representative party of the Association to visit New Zealand during his term of office had to be indefinitely postponed.

The first ceremony in connection with the Clerk Maxwell Celebration was performed in Westminster Abbey on Wednesday, September 30, when Memorial Tablets to Faraday and Maxwell were unveiled by the Master of Trinity; they lie adjacent to the tomb of Sir Isaac Newton. Thereafter the proceedings were held in Cambridge. On Thursday, after an official luncheon in the Hall of Corpus Christi College, presided over by the Vice-Chancellor, who is also Master of Corpus, an academic procession was formed and proceeded to the Senate House, where the delegates were officially received and a Memorial Lecture on Clerk Maxwell was delivered by the Master of Trinity. Thereafter a reception was held at Peterhouse, and an evening reception took place at St. John's. On Friday, morning and afternoon sessions were devoted to addresses on the life and scientific work of Clerk Maxwell: in the morning by Max Planck, Niels Bohr, Sir Joseph Larmor, and Lord Rutherford, and in the afternoon by Sir James Jeans and Maxwell's contemporaries, Dr William Garnett, Sir Ambrose Fleming, Sir Oliver Lodge, and Sir Richard Glazebrook. The Vice-Chancellor was then "at home" in Corpus Christi College, and concurrently a display of Maxwell apparatus and manuscripts was shown in the Cavendish Laboratory. Here also an interesting demonstration of a new process in colour kinematography was given, one of the subjects being the academic procession of the preceding day. The proceedings terminated with a magnificent banquet in the great hall of Trinity College. The whole atmosphere of this gathering, the candle light, the boys' voices in the choir singing the grace-anthem, and the beautiful words expressed by the Master of Trinity, General Smuts, and Sir Oliver Lodge in proposing and responding to the toast of "The Guests" will not easily be forgotten, and formed a wonderful climax to this most impressive series of commemorations.

NATIONAL RESEARCH COUNCIL AND FELLOWSHIP NEW ZEALAND INSTITUTE.

The incorporated societies were asked to consider the proposals approved by last Annual Meeting of the Board of Governors, and reports were received as follows:—

Philosophical Institute of Canterbury.

A. National Research Council:

1. That the constitution of the National Research Council should be such as not to interfere in any way with the New Zealand Institute as a body to which scientific questions might be referred. The National Research Council should be approached through, and should report through, the President of the New Zealand Institute.

2. That the Fellows of the New Zealand Institute are not necessarily all suited for membership of the National Research Council, and there are persons outside the Fellowship who are eminently qualified for membership of a National Research Council, and that therefore members of the National Research Council should be appointed independent of the Fellowship.

3. (a.) That the New Zealand Institute should appoint five men, who must be of recognised scientific attainments, and thoroughly representative of the basic sciences, to form the nucleus of the National Research Council.

(b.) These five should then select 15 others, to be members of the National Research Council, with due regard to their scientific qualifications and to adequate representation of the various branches of science.

4. That the members of the National Research Council selected under Clause 3, or a Committee thereof, be empowered to frame regulations as to period

of office and other matters having to do with the constitution of the Council, and should then proceed at once, or from time to time, to co-opt other members to the Council, always provided that the total number should not at any time exceed 50.

B. Fellowship New Zealand Institute:

1. That the present method of election to the Fellowship is not satisfactory.

2. That the Fellows should indicate by a system of preferential voting their choice of new Fellows from among those nominated by the constituent Institutes.

3. That the final selection of Fellows be made by a Committee selected and working as follows:—

(a.) Five in number.
(b.) Selected by the New Zealand Institute from the Fellows.
(c.) To consist of men of recognised scientific attainments and thoroughly representative of the various branches of science.
(d.) To meet and discuss the qualifications of the candidates with due regard to their scientific attainments, to the preferences of Fellows, and to the due representation of the various branches of science.
(e.) Proviso added by Council of Canterbury Philosophical Institute: That provision be made for the periodic retirement of members of this Committee.

Auckland Institute.

1. That the constitution of a National Research Council around Fellowship of the New Zealand Institute as a nucleus be approved, with the further recommendation that the National Research Council be established on the lines of the proposal of the Auckland Institute, agreed to by the Annual Meeting of the Board of Governors in 1930.

2. That Nos. 2 and 3 be replaced by the following:—"That the election of Fellows as at present be abolished, and that nominations be made annually by incorporated societies; but that nominees should not be informed of their nomination. That the nominations be submitted to a special Committee, which shall recommend to the Board of Governors those who should be invited to accept the Fellowship. That the Committee should be directed to have reasonable regard for the distribution of the honour among the different sciences; but that it should be in no way tied to this principle.

3. That the deletion of 4 be approved.

Nelson Institute.

That the various clauses amended by the Annual Meeting of the Board of Governors be approved of.

None of the other societies has reported on these proposals.

The report of the incorporated societies on these subjects was before the meeting. Professor Worley stated that the scheme proposed by the Auckland Institute had previously been approved by the Board of Governors. Professor Worley was informed that the Auckland Institute's scheme had been superseded by a scheme approved by the last annual meeting of the Board for consideration and report by the incorporated societies. This scheme had been submitted to the societies.

Professor Speight moved that the amended proposals of the Philosophical Institute of Canterbury be considered clause by clause.

National Research Council:

No. 1.—That the constitution of the National Research Council be such as not to interfere in any way with the New Zealand Institute as a body to which scientific questions might be referred. The National Research Council should be approached through, and should report through, the President of the New Zealand Institute.

This clause was approved.

No. 2.—That the Fellows of the New Zealand Institute are not necessarily all suited for membership of the National Research Council, and there are persons outside the fellowship who are eminently qualified for membership of a National Research Council, and that therefore members of the National Research Council should be appointed independent of the Fellowship.

This clause was approved.

No. 3.—(a) That the New Zealand Institute should appoint five men, who must be of recognised scientific attainments and thoroughly representative of the basic sciences, to form the nucleus of the National Research Council.

(b) That these five should then select 15 others to be members of the National Research Council, with due regard to their scientific qualifications and to adequate representation of the various branches of science.

It was resolved to insert after "others" in (b) the words "subject to approval of the Board of Governors or of the Standing Committee." Approved.

No. 4.—That the members of the National Research Council selected under Clause 3, or a Committee thereof, be empowered to frame regulations as to period of office and other matters having to do with the constitution of the Council, and should then proceed at once, or from time to time, to co-opt other members to the Council, always provided that the total number should not at any time exceed 50.

This clause was approved.

On the motion of Dr Kidson it was resolved that it be a recommendation to the persons selected under Clause 3 that in framing the necessary regulations they give special consideration to the recommendations of the Auckland Institute.

On the motion of Professor Speight, seconded by Dr Farr, it was resolved that the first five be elected by the Standing Committee after due consideration.

Some discussion took place as to how the National Research Council could be financed, but it was considered that all the preliminary business could be done by correspondence, and the question of finance need not at present arise.

Fellowship:

No. 1.—That the present method of election to the Fellowship is not satisfactory.

Some discussion took place in regard to this clause, and finally on a show of hands it was approved.

No. 2.—That the Fellows should indicate by a system of preferential voting their choice of new Fellows from among those nominated by the incorporated societies.

It was decided to delete the words " a system of preferential." Approved as amended.

No. 3.—That the final selection of Fellows be made to the Board of Governors by a Committee selected and working as follows:

It was decided to substitute " recommendations for the Fellowship " for the words " selection of Fellows."

(a) Five in number.
(b) Selected by the Board of Governors of the New Zealand Institute from the Fellows.
(c) To consist of men of recognised scientific attainments and thoroughly representative of the various branches of science.
(d) To meet and discuss the qualifications of the candidates with due regard to their scientific attainments, to the preferences of the Fellows, and to the due representation of the various branches of science.
(e) That one member retire every year, and the Standing Committee formulate the necessary arrangements.

Approved as amended.

The Auckland Institute submitted the following recommendation:—" That the election of Fellows as at present be abolished, and that nominations be made annually by incorporated societies, but that nominees should not be informed of their nominations. That the nominations be submitted to a special Committee, which shall recommend to the Board of Governors those who should be invited to accept the Fellowship. That the Committee should be directed to have reasonable regard for the distribution of the honour among the different sciences, but that it should in no way be tied to this principle."

It was resolved to delete the words " but that nominees should not be informed of their nomination." Approved.

It was resolved that in future members of the Board of Governors who are not Fellows be also supplied with the information regarding the qualifications of those selected for the Fellowship.

Later it was resolved on the motion of Dr Kidson, seconded by Dr Farr, that Dr L. Cockayne, Dr P. Marshall, Dr W. P. Evans, Dr E. Marsden, and Professor Kirk be members of the Committee to advise the Board of Governors re candidates for election.

Dr Cockayne's Resignation: The President stated that he regretted to announce the retirement of Dr Cockayne from the Board of Governors of the New Zealand Institute. On rising, Dr Cockayne was given an ovation by the members of the Board. He stated that he had come that day to say " good-bye " and wish the best of good luck to the New Zealand Institute, which had been the making of him. His eyesight now was such that he could not attend meetings, and he felt that he should retire.

Mr G. M. Thomson said he wished to express the great regret of the Board at Dr Cockayne's retirement. He had done great work on the Board. He referred to Dr Cockayne's great vigour, physically and mentally, and his wonderful store of scientific knowledge. He trusted that Dr Cockayne would be spared many years to complete the work he had in hand. In retiring he carried with him the best wishes of the Board and the societies which it represented.

Professor Easterfield endorsed Mr Thomson's remarks. He said that Dr Cockayne, Mr Thomson, and he had come on to the Board at the same time, and during the years of their association Dr Cockayne had shown a wide tolerance in all matters that came before the Board. They would greatly miss his opinions. He trusted that Dr Cockayne would still be able to continue his interest in the Board and stimulate younger men to take an interest.

Dr Cockayne, in thanking Mr Thomson and Professor Easterfield, remarked that he had just published six articles which he had dictated.

The President, Professor Segar, said that Mr Thomson and Professor Easterfield had expressed the views of the Board, and he could only again express their utmost regret at Dr Cockayne's retirement. Dr Cockayne then said " good-bye " to each of the members of the Board and retired.

NATURAL SCIENCE IN SCHOOLS.

Professor H. W. Segar,
President of the New Zealand Institute.

DEAR SIR,—

I enclose the report of the Committee set up at last Annual Meeting to report on the teaching of natural science in all schools in the Dominion, the Committee consisting of Hon. G. M. Thomson, Messrs G. V. Hudson, W. R. B. Oliver, and myself.

Faithfully yours,
H. B. KIRK, Convener.

Report of Committee.

It has not been possible for the Committee to go so fully into the matter of the teaching of natural science in all schools as to justify it in regarding its report as more than a summary of the views gained from the sources of information to which it has had access.

The Committee wishes to acknowledge the ready help of Mr T. B. Strong, Director of Education, and of Mr A. J. H. Benge, Secretary to the Education Department. The Committee expresses its appreciation of the many sympathetic answers sent by headmasters of secondary schools, and of several others to letters written by Mr Thomson, seeking information as to what was being done with regard to the teaching of Natural Science.

Primary Schools.—So far as the aim goes the provision for the teaching of natural science in the primary schools from the kindergarten upwards appears to the Committee to be well planned, and the directions given appear to be adequate. There is evidently a keen sympathy on the part of the directing authorities with the encouragement of first-hand observation on the part of the scholars. That the aim is not more fully achieved we believe to be due to the fact that only a small proportion of the teachers have such scientific training as fits them to deal adequately with nature study. That training is not obtained most effectively by a course of study of a discursive kind covering the ground that the teacher will afterwards have to traverse with his pupils, but by as thorough a study as is possible for some one or more branches of science enabling the teacher to adapt himself to the circumstances in which he may find himself with his pupils. Such a training will not enable him to answer at once all the questions that may occur, but it will place him in a position to find the answer to most of them. But the conditions in which student teachers find themselves at the Training Colleges when seeking qualifications for the higher certificates are not such as to favour study of the observational and experimental sciences. The trainee has to secure his formal teaching qualification and to pursue his University studies at the same time. Thus there is a strong inducement to him to choose such subjects as will take the least time and to avoid the subjects in which practical work makes great demands upon him. We believe that proper study of the basic sciences can be rendered possible, so far as the greater number of student teachers taking a University course are concerned, by a separation of the period of University education from that of normal school training, though that separation need not be a complete one.

Primary and Secondary Schools.—The encouragement of school gardens should, we think, be extended as far as may be. Experience shows that a perfectly astonishing interest can be aroused by teachers that have inclination for this kind of work, both teacher and pupils becoming enthusiastic, and the prosecution of the work enlivens and stimulates the general work of the school. Similar results to those just referred to follow in the schools in which pupils are encouraged to bring to their teachers any objects, whether animal, vegetable, or mineral, that interest them. In such cases the teacher is a fellow-student with his pupils, and the mere fact that they help in obtaining the information desired is of the very greatest value.

It is felt that the co-operation of the University professors whose subjects specially fit them to co-operate will give sympathetic help to all teachers who have need of help that it may be in their power to give.

In this connection it seems that the Institute might, if funds can be raised for the purpose, be of use in offering prizes for competition. The competitions should be designed to interest the children in nature study in the field, and those only should be eligible as candidates who collect and observe. It seems not impossible that the Institute, at a later time, might find itself in a position to offer such considerable prizes to the schools themselves as would constitute a real incentive to the teaching of the observational sciences, and a welcome addition to the capitation subsidies already granted by the Government for all science subjects.

Secondary Schools.—Answers to letters sent out by Mr Thomson show that there is a fairly general recognition of the value of natural science from the point of view of culture and real education. There is much sympathy on the part of secondary schools' heads, and there is benediction of effort, but they have to bear in mind that there is little incentive to a school to teach the observational science subjects. This is in no little measure due to the syllabuses of examination to which the school must have regard, notably the University Entrance Examination, the Entrance Scholarship Examination, and the Public Service Entrance Examination.

With respect to the first two of the examinations just mentioned, the teachers themselves, in virtue of their representation on the Entrance Board, are in a strong position to advocate change of the prescriptions. Bearing in mind that the prescriptions do not constitute the whole difficulty, and bearing in mind, on the other hand, the great cultural value of the natural science subjects, the Committee recommends that the following changes be sought:—

Entrance Statute.—That sub-clause 5 of clause II of the Entrance Statute (p. 22 of the University Calendar for 1932) should be amended to permit of a candidate taking more than two of the subjects of the science group—Mechanics, Physics, Home Science, Chemistry, Botany, Agriculture; that there should be included in this science group the subjects Zoology and Geology; further, that a candidate taking Chemistry should not be allowed to take Home Science, seeing that the prescription in the latter subject comes almost entirely under the subject Chemistry, together with such knowledge of Physics as is inseparable from elementary Chemistry.

That Zoology and Geology should be included in subjects that may be taken for the Entrance Scholarship Examination, and that, in view of the amount of time that is required for effective study of the observational and experimental science subjects, the maximum marks obtainable for each such subject should not be less than 400, the maximum allowed for French and for German.

That Zoology and Geology should be included in the subjects that may be taken at the Public Service Entrance Examination.

School Curricula.—The Committee is strongly of opinion that Botany should have a place in the curriculum of all Girls' High Schools. Botany has in recent years been displaced almost entirely by Home Science and History, neither of which, in the opinion of the Committee, has the same educational value. The practical side of the teaching of the subject should be really practical. It is also of opinion that some natural science subject should have a place in the curriculum of every Boys' High School.

As showing the small place that Botany now holds in the secondary schools, reference may be made to the Annual Report of the Chief Inspector of Secondary Schools for 1931, E6, Table 4. It shows that the subject is taken by 120 boys in a total of 8838 (1.4 per cent.) and by 347 girls in a total of 7030 (4.5 per cent.).

Field Clubs.—The Committee is of opinion that in all High Schools and Technical High Schools in which there are teachers capable of co-operating the establishment of Field Clubs should be encouraged.

On the motion of Professor Kirk, Convener of the Committee which drew up the report, the report on Natural Science in Schools was adopted.

Mr G. M. Thomson, a member of the Committee, stated that, recognising the futility of circular letters, he had written personal letters to every headmaster and headmistress of secondary and technical schools, and he had received over 90 per cent. of replies.

It was resolved that the report be forwarded to the Academic Board and the Senate.

Number of Fellows to be Elected in 1933: It was resolved that not more than two Fellows be elected.

Hutton Grants: The Vice-president read the applications which had been received for grants from the Hutton Fund.

Mr F. J. Turner's application (held over from last year) was considered, and it was resolved to grant him £30 for a geological expedition to the south-west portion of Otago.

Mr C. E. Christensen's application (held over from last year) for a grant of £25 for collecting hybrid plants at Hanmer was granted. Applications from Mr L. C. King, Dr O. Frankel, and the Waitemata Harbour Survey Committee were approved, subject to confirmation by the Standing Committee. The total amount of grants for 1932 not to exceed £125.

On the motion of Dr Farr, seconded by Mr Eliott, it was resolved that in future applications for Hutton grants be considered by the Standing Committee, and that they report to the Annual Meeting.

Carter Library Legacy: Mr Oliver mentioned that there was an amount of £208 in the Carter Library Legacy which has accrued from an amount of £50 left to build a room in which to house the Carter Library. Mr Oliver moved and Professor Kirk seconded: "That all moneys standing to the credit of the Carter Library Legacy Account be reserved for providing fittings for the Library of the New Zealand Institute (in which room the Carter Library is to be housed), provided the approval of the executors of the will of C. R. Carter be obtained. Failing this, the moneys be allocated to the General Building Fund of the Dominion Museum and National Art Gallery, but held by the Institute until building operations have been commenced."

Some discussion took place on the legality of either procedure, and it was finally resolved on the motion of Professor Easterfield, seconded by Mr Aston, that the matter be left in the hands of the Standing Committee with power to act, after having had legal advice from the Public Trustee, who holds the original legacy of £50, the nucleus of the Fund.

Notices of Motion were then taken. On the motion of Mr Aston, seconded by Mr Eliott, it was resolved that the New Zealand Institute takes this opportunity to offer to the Government its appreciation of the financial difficulties which it and all other Governments are facing, and further assures the Government that this Board always has taken, and is now taking, steps to reduce the cost of administration, so that whatever reduction in the annual Parliamentary grant is made this Board will cordially abide by the decision of Parliament, and will endeavour to carry on the work of publishing original scientific work so that no discovery submitted shall go unrecorded.

A motion proposed by Mr Oliver, seconded by Mr Hudson: "That meetings of the Standing Committee be held either at the Dominion Museum or in the New Zealand Institute Library at Victoria University College," was lost.

An amendment moved by Mr Aston, seconded by Mr Eliott: "That the matter be referred to the Standing Committee, with power to act," was carried.

A motion proposed by Mr Hudson, seconded by Professor Speight: "That the present system of referring papers to referees be discontinued, and that if the opinion of a specialist be required the paper be referred to an authority overseas," was lost.

A motion proposed by Mr Oliver, seconded by Mr Hudson: "That the Secretary be authorised to accept annual subscriptions for the *Transactions* at the rate of £1 per annum," was referred to the Standing Committee, with power to act.

Spectrohelioscope: The President stated that he had a letter from Dr Adams stating that an offer of a spectrohelioscope had been made to New Zealand, and he asked that a Committee be set up to see if steps could be taken for a building to be erected to house this instrument. On the motion of Dr Farr it was resolved that Dr Kidson, Dr Marsden, Professor Sommerville, and Dr Adams be a Committee set up to look into the matter and report to the Standing Committee.

Waitangi Estate: A motion of appreciation of their Excellencies' generous gift of Waitangi to the Government was carried by acclamation.

Election of Officers: President, Professor H. W. Segar; Vice-president, Mr B. C. Aston; Hon. Treasurer, Mr M. A. Eliott; Hon. Editor, Professor D. M. Y. Sommerville; Hon. Librarian, Professor D. M. Y. Sommerville; Hon. Returning Officer, Professor H. W. Segar; Managers Trust Accounts, Mr M. A. Eliott and Mr B. C. Aston; Representative on the Institute of Horticulture, Mr B. C. Aston; Representative on the Great Barrier Reef Committee, Mr W. R. B. Oliver.

Committees:

Hutton Award Committee.—Dr Marshall, Dr Holloway, and 1932 recipient of award.

Hector Award Committee.—Professor Speight, Dr Marshall, and Dr Cotton.

Hamilton Award Committee.—Dr Marshall and Dr Benham.

Finance Committee.—Messrs Eliott, Aston, Dr Marsden, and Dr Kidson.

T. K. Sidey Summer Time Fund Award Committee.—Dr Marsden, Professor Easterfield, and Dr C. E. Hercus.

Library Committee.—Professor Sommerville, Professor Kirk, and Dr Cotton.

Votes of Thanks to the Honorary Officers, to the Secretary, to the Press, and to Victoria University College were passed.

Annual Meeting, 1933: It was decided to hold the Annual Meeting, 1933, in Victoria University College, date to be fixed by the Standing Committee.

PRESIDENTIAL ADDRESS

Delivered at the Annual Meeting at Wellington on 19th May, 1932.

By PROFESSOR H. W. SEGAR, M.A., F.N.Z.Inst.

GENTLEMEN,—

My first duty is to refer briefly to some losses we have sustained through death during the past year.

Dr J. P. Lotsy, of Holland, is, I think, the only honorary member who has died during the year. Dr Lotsy was a world authority on hybridism. He visited New Zealand a few years ago to study his subject and confer with the Dominion's authority in his own line—Dr L. Cockayne. Though Dr Lotsy was primarily a botanist, his studies of hybridism covered a wide range, and his passing away is a heavy loss to the scientific world.

The loss of one of our foundation fellows, and a Hector Medallist, has to be recorded in the person of Mr Elsdon Best. A very full obituary notice has already been published on pp. 179-182 of vol. 62 of the *Transactions,* but we may here record our sense of the great loss sustained by New Zealand in the death of such a great contributor to our knowledge of native races in general and in particular of our own, the Maori. He is an instance of the type of man, in prominent examples of which our race has been rather rich, who, without the aid of anything in the nature of academic preparation, takes up with enthusiasm some particular study, and by reason of native ability, unstinted devotion, and often considerable self-sacrifice, becomes a great authority and makes a great contribution to human knowledge.

Another past member to whom I should refer on this occasion is the late Mr John Kenderdine, for many years, and up to the day of his death, a member of the Council of the Auckland Institute and of the Library Committee of the Auckland City Council. He was particularly interested in the early history of New Zealand, and built up a large collection of books and pamphlets. This collection includes very many pamphlets dealing with all phases of public life in the Auckland Province from early dates to the present time. The whole of his collection was presented to the Auckland Institute shortly before his death.

We have further to mourn the death of Dr H. T. Ferrar, who was on the New Zealand Geological Survey staff, and to whom the Institute is indebted for the British Association Reports from 1919 to date; and also the untimely death of Dr F. G. Maskell, B.A., M.Sc., Ph.D., who was Lecturer in Biology in Victoria University College, and who was doing research in Germany when he contracted an illness that cut short a career of great promise.

In proceeding to make some remarks on the general affairs of the Institute, I am keeping in mind that any time saved in this address can, with advantage, be added to the time available for the discussion of the important business of the meeting.

The Economic and Financial Situation.

The dominant influence during the past year has been the economic and financial situation of the country, and the Institute has been brought into direct contact with it by the reduction and withdrawal of grants by Parliament, with the resulting crippling of the work of the Institute. The New Zealand Institute was established by special Act of Parliament in 1867, and in the following year an annual grant of £500 was made to the Institute. At that time the population of New Zealand was only approaching a quarter of a million. Its total trade was less than £9,500,000. The total deposits in its Savings Banks, both post office and private, were less than £250,000, or about £1 per head of population; and in every other direction we find that every resource, or indicator of resources, was on a similar but very much smaller scale than now. Yet the infant country thought the publication of the results of the researches of its scientists, which is the essential work of the New Zealand Institute, of such importance that, out of its comparatively slender resources, it determined to devote £500 a year towards the maintenance of the society that had charge of the work. Below this figure the annual grant has never fallen, not even, be it noted, during the great and long depression of the late 'eighties and early 'nineties of the last century. On the other hand, during more recent years the increase of the work of the Institute, together with the increase in the cost of printing and other costs, led to increases in the annual grant, bringing it up to £1500, at which figure it stood two years ago. To this had been added for some years votes varying from £750 to £1250 for the purposes of research work, and this facilitated considerably the carrying out of research where expense to the investigator was necessarily involved.

My predecessor, at the last Annual Meeting, commented on the entire withdrawal of the latter vote, and the cutting down of the ordinary annual vote to one-half (£750), both of which had been effected before the last Annual Meeting. As a consequence of this loss the Standing Committee was for some time sorely tried during the past year to make ends meet and to save the *Transactions* from sinking into insignificance. The situation was eased a little, however, by one fortunate circumstance. There was a balance of £440 of the research grant remaining unexpended, and the Government was urged to allow this to be paid and used for printing expenses. This was fortunately agreed to. But in spite of this you will no doubt have noticed that the last volume of the *Transactions* contains only some 270 pages, as contrasted with the 1000 and more that used to be sometimes reached. Some papers that would otherwise be printed have to remain unprinted, and those that are printed are in some cases so reduced and condensed as possibly to materially diminish their value.

It will be readily understood then that we were amazed to find that the Economy Commission actually recommended that the grant should be further reduced to as little as £400. Protests were naturally made against this, and every member of Parliament was circularised, but the final result was only to obtain, instead of the expected £400, a vote of £500, just equal to the vote the Institute started with nearly 70 years ago. Even this now is no longer statutory. This means a total loss in the ordinary grant of £1000 a year, which has to be made good for the most part by a saving of an equivalent amount in our ordinary expenditure, unless funds be raised in some manner which so far we have not been able to contrive. It may be noted incidentally that the item "Printing, Stationery, etc.," of the expenditure side of the Revenue Account, which two years ago stood at £1424 0s 10d, and last year at £1342 19s, amounts this year to £208 10s 7d.

The Government was criticised in the House a week or two ago for reducing the taxation of the racing clubs. This was defended by the plea that it was done to save the goose that laid the golden eggs. It may reasonably be urged that science is a goose that has been very prolific in the laying of golden eggs, and from the point of view merely of profit deserves every care and attention. It is often quoted how other countries, when they have been in positions of distress, have made sacrifices in other directions in order to improve the education and scientific equipment of their peoples. We must have every sympathy with our own Government in the position in which they have been recently placed; but at the same time we may reasonably urge that we do not consider they have shown a due sense of values in penalising so heavily the educational and research institutions of the country. In our own case we are already reduced to the rather scornful position of having to invite scientific workers, by no means an affluent section of our population, to contribute towards the publication of their results for the national benefit.

The Library.

Our privations apparently remove to a more distant future any hope of putting our Library on a proper basis. The mainstay of our Library at present are the exchanges we get in return for the distribution of our *Transactions* to the various scientific societies of the world. How wide this is is not perhaps generally known or appreciated. Sets of the *Transactions* are to be found in the chief scientific libraries of the world, the number in the several countries being as follows:—Austria 5, Belgium 5, China 2, Denmark 4, Finland 4, France 8, Germany 30, Holland 6, Hungary 3, Italy 15, Japan 4, Norway 5, Malay States 3, Russia 10, Spain 3, Sweden 10, Switzerland 4, South America 8, United States 59, and the British Empire 150.

Obviously it may be remarked incidentally this extensive distribution of our *Transactions* in its present starved condition will not be a good advertisement for New Zealand, nor will it produce in the world of science a very high opinion of New Zealand.

The Institute has never had any money with which to supplement the exchanges received for the *Transactions,* and to buy standard works of science, and has consequently had to go without numerous important and really essential publications. Further, the binding of such publications as we have is an expensive item, and for this purpose we have been dependent on one totally inadequate grant of £250, which has been husbanded for years by confining the actual binding to only the most essential publications. Even using the cheapest binding available in New Zealand, the remainder of this fund will be almost immediately absorbed. Yet the need for binding the publications in the Library is so great that some hundreds of pounds is really required at once for this purpose alone, especially in the direction of binding in volumes publications which are issued in small parts.

Money is wanted for still another purpose. The Institute published in 1927 a Reference List of Scientific Periodicals in the libraries of New Zealand. This list shows in which libraries in New Zealand various periodicals can be found, and served to mobilise the whole of the libraries of New Zealand as one unit for the service of the scientific worker. An enlarged and up-to-date edition is now urgently required, and it is only the absence of funds that prevents the work being put in hand at once. We are hoping that our doleful account of our Library requirements, which was made a leading feature in the statement of our case in our appeal to the Carnegie Corporation of New York, will soften their hearts, but it is sad to have to seek aid abroad for what should be deemed an essential obligation by our own people.

Reform of the Institute.

Out of present necessities arose a suggestion to increase the income of the Institute by altering its constitution. I say altering rather than reforming, because the word reform has come to connote improvement, and to take for granted that a proposed change will be an improvement is to beg the question. The proposals were put before the incorporated societies, and after the opinions of these had been obtained were referred to a committee to report. This report will no doubt be presently before you. In considering it I would suggest that viewing it from the point of view of financial return does not create the best atmosphere for its consideration, and in any case there must be a certain amount of speculation about a venture of this kind. It would be safer to make a change when we are in a position to stand any loss that may be incurred, and it is proverbially dangerous to swop horses while crossing a stream. In better times the possibility of an improved constitution could be considered without our judgment being warped by financial necessity. In particular the proposal to increase the subscription rate of Fellows of the Institute, when they have no substantial privilege or advantage beyond that of ordinary members, is one that, by levying a tax for the mere use of the symbol F.N.Z.Inst., may react in ways that the Institute would not appreciate. We do not want the fellowship of the Institute to be comparable with that of vice-president of a sports club, or to have the fellowship declined by worthy scientists because of the financial obligations involved. This particular proposal may not appear in the Report of the Committee, but in whatever form the proposals come from the Committee very careful consideration should be given and hasty action avoided in a matter so fundamental as that it will deal with.

Endowment Fund.

It would be of great advantage to the Institute if we had an endowment fund adequate to support its activities without the necessity of outside grants. The Standing Committee has wisely decided on a policy which is designed to add annually to the fund, but which will take a very long time to make the fund sufficient for its purpose. Yet I hope, as a move in this direction, the action of the Standing Committee will meet with your approval. But what I most hope for is that some day some benefaction or benefactions will be received that will more speedily raise the position of the Institute to one of independence. Many of our citizens well endowed with this world's goods, who expect to leave no dependents behind them, or are able to provide amply for their dependents and still have a surplus, endow from time to time one good cause and another. I claim that the work of the New Zealand Institute is eminently deserving of consideration in this respect, and that any wealthy citizen who appreciates our work, or perhaps has reason to realise that his fortune was only made possible by the advance of science, may well deem it a specially worthy object to make secure the adequate permanent recording of the scientific advances in his own country, and to make the Library of the Institute really worthy of the place it should occupy as an aid to scientific work.

The Genus Liothyrella (Brachiopoda) in New Zealand.

[With 3 plates.]

By R. S. ALLAN, M.Sc., Ph.D., F.G.S., National Research Scholar.

[*Read before the Otago Institute, 11th November, 1930.*]

IT has been shown by J. Allan Thomson (1927, pp. 196-8) that the New Zealand Tertiary Terebratulids referred by him to *Liothyrella* are not uniform as regards loop-characters; some species approach the Liothyrella-type, while others agree more closely with the Gryphus-type of loop. The genotypes of *Liothyrella* Thomson, and *Gryphus* Megerle von Muhlfeldt (see Thomson, 1927, for details), are not available to the writer, and in this revision the whole of the New Zealand species, Recent and Tertiary, are referred to *Liothyrella sensuo lata.*

Liothyrella J. A. Thomson 1916.

1916. *Liothyrella* Thomson, *Trans. N.Z. Inst.*, 48 (Oct. 16), p. 44.
1918. *Liothyrella* Jackson, *Geol. Mag.*, Dec. 6, vol. 5, pp. 73-79.
1927. *Liothyrella* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 197-8.

Type (by original designation): *Terebratula uva* Broderip 1833 (see Thomson, 1927, p. 197, fig. 59).

Generic Diagnosis: Ovate, biconvex Terebratulidae which are uniplicate to sulciplicate; test smooth, finely punctate. Beak short, foramen epithyrid, marginate to labiate, symphytium almost hidden. Hinge-teeth without dental plates or swollen bases. Hinge-plates divided; cardinal process small, transverse. Loop short, triangular, the descending branches diverging anteriorly and meeting the transverse band in a sharply pointed angle.

Specific Characters: In the specific descriptions which follow, it will not be necessary to repeat what already appears in the generic diagnosis above. The introductory word "*Liothyrella*" implies that the species conforms to the generic description given.

The features of specific importance are:—(1) Shape and size; (2) relative convexity of the valves; (3) degree of foraminal development; (4) the stage of evolution reached by the anterior commissure, i.e., the folding; and (5) the detailed nature of the loop.

This specific revision includes the species previously described by Suess, Hutton, Hamilton, Boehm, and Thomson, viz.:—

Waldheimia gravida Suess 1864.
Waldheimia concentrica Hutton 1873.
Terebratula oamarutica Boehm 1904.
Terebratella kakanuiensis Hutton 1905.
Terebratella neglecta Hutton 1905.
Magellania magna Hamilton 1910.
Liothyrella boehmi Thomson 1918.
Liothyrella landonensis Thomson 1918.
Liothyrella neozelanica Thomson 1918.
Liothyrella pulchra Thomson 1918.

The whole of these species were described in manuscript left by J. A. Thomson, and written during, or prior to, 1918. I have to thank Mr W. R. B. Oliver, Director of the Dominion Museum, for permission to make use of this valuable manuscript. The actual descriptions needed careful editing, and could not be used without considerable addition and emendation, but nevertheless were invaluable to a student beginning to study Tertiary brachiopoda. Actually the specific diagnoses which follow, while they owe much to the late Dr Thomson's preliminary work, are based almost entirely on personal study of genotypes or topotypes.

For permission to redescribe the types of Hutton's species, the writer must thank Professor R. Speight, Curator of the Canterbury Museum. Mr W. R. B. Oliver has kindly forwarded the types of the species described by A. Hamilton and J. A. Thomson.

Terebratula oamarutica Boehm has been studied in the form of topotypes. *Waldheimia gravida* Suess, of which the type is in Vienna, and of which topotypes are not available, must remain an unsatisfactory species.

The new species result from the study of material collected by Dr J. Marwick and the writer from the Chatham Islands in 1924-1925; and of additional specimens collected by the writer in Otago and Canterbury.

DESCRIPTION OF SPECIES.

Liothyrella boehmi J. A. Thomson 1918. (Pl. 3, Fig. 5).

1918. *Liothyrella boehmi* Thomson, in J. Park, *N.Z. Geol. Surv. Bull.* No. 20, p. 118, not figured.

Diagnosis: A *Liothyrella* of large size (about the size of *L. gravida,* larger than *L. concentrica* and *L. oamarutica,* but considerably smaller than *L. magna*); greatest breadth anterior to the middle; ratio of length to breadth, 1 : ·77; in shape elongate-ovate; anterior commissure broadly uniplicate; beak prominent, obliquely truncated by a large foramen which is broadly marginate, and may show incipient labiation; valves strongly biconvex.

Dimensions of holotype: Length, 52mm.; breadth, 40mm.; thickness, 32mm.

Type locality: Tuffs underlying limestone, Everett's Quarry, Kakanui. Collected by A. McKay, 1882. Middle Ototaran.

Type in the Dominion Museum, Wellington.

Distribution: Material from the following localities has been examined:—

(a) Calcareous tuffs, Trig. M., near Totara; not uncommon. Age: Lower Ototaran. Coll. R.S.A.

(b) Tuffs below limestone, Flume Creek, Papakaio. Age: Middle Ototaran. (See J. Park, 1923, pp. 80-2).

(c) Limestone, Upper Target Gully, Oamaru. Age: (?) Upper Ototaran. R.S.A. coll.

(d) Conglomerate, Rifle Butts. Age: Basal Hutchinsonian. R.S.A. coll.

(e) Conglomerate, coast north of Kakanui. Age: Basal Hutchinsonian. (Common). R.S.A. coll.

Remarks: The type is slightly damaged on one side, and has part of the ventral shell missing; it is not a fully adult specimen. The species is not uncommon at the type locality, but it is extremely difficult to extract from the tough matrix. *L. boehmi* appears to range throughout the Ototaran, but the writer has not been able to find a single specimen in the Upper Ototaran of Kakanui (Everett's Quarry). Thomson (1926, p. 152) has recorded "*Liothyrella* cf. boehmi" from the *landonensis*-fauna of Landon Creek and Flume Creek, but the species is not known to occur in the Waitaki limestone (Waitakian). This fact makes its presence in the basal Hutchinsonian conglomerate a matter of suspicion. Concerning the basal Hutchinsonian localities, J. A. Thomson wrote: "Large specimens of *Liothyrella* occur in most localities [All Day Bay, Kakanui, Deborah, Ardgowan, Hutchinson's Quarry, and Devil's Bridge], and were previously referred to *L. boehmi,* but the best preserved specimens are broader and less convex than that species, and probably a distinct species." (1926, p. 150). Thomson may be correct, but my own collection from the Rifle Butts, and Kakanui, does not bear out his contention. The basal Hutchinsonian specimens are, therefore, referred to *L. boehmi,* with the suggestion that they may be derived fossils of Ototaran age (cf. Thomson, 1926, p. 154). If they are not derived then the species has a curious discontinuous vertical range. It is not known outside the Oamaru district.

Liothyrella concentrica (F. W. Hutton 1873). (Pl. 1, Fig. 4).

1873. *Waldheimia concentrica* Hutton, *Cat. Tert. Moll. Ech. N.Z.*, pp. 35-6, not figured.

1905. *Terebratula concentrica* Hutton, *Trans. N.Z. Inst.*, 37, p. 474, pl. XLV, fig. 1.

Diagnosis: A *Liothyrella* like *oamarutica* (Boehm), but differing in the greater elongation (ratio of length to breadth, 1 : ·64); and in the narrowly marginate foramen, the anterior part of which projects dorsally of the hinge-line.

Type locality: Hutton (1873) gave the following localities: Chatham Islands, Broken River (lower beds), Culverden, Pakau, and Castle Point. In 1905 he figured two specimens from Broken River, which is therefore selected as the type locality.

Lectotype: The material from Broken River studied by Hutton (1905) consists of two specimens which may be regarded as syntypes. One (Hutton, 1905, pl. XLV, fig. 1, upper figure) is distorted, and part of the ventral valve is missing; the other (Hutton, 1905, pl. XLV, fig. 1, lower figure) is complete, and is therefore selected as lectotype.

Lectotype in the Canterbury Museum.

Dimensions of lectotype: Length, 37mm.; breadth, 24mm.; thickness, 19mm.

Liothyrella gravida (E. Suess, 1864). (Pl. 1, Fig. 2).

1864. *Waldheimia gravida* Suess. In K. A. Zittel, Novara Exped., *Geol. Theil.*, Bd. 1, Abth. II, Paläont. von Neu-Seeland, pp. 56-7, taf. IX, figs. 5a, b.

Type locality: Papakura limestone quarry, near Auckland.

Type in the K.-K. Hofmuseum, Vienna.

Remarks: Suess figured the interior and exterior of a ventral valve, but the interior is filled with matrix. Thomson (in MSS.) records that attempts made by Dr C. A. Cotton, Professor J. A. Bartrum, and Mr E. de C. Clarke to secure topotypes have so far failed. It is a matter of regret that this species must be left in an unsatisfactory position.

Provisional Diagnosis: A *Liothyrella* of large size in which the length is only slightly greater than the breadth, and in which the foramen is strongly labiate.

Distribution: Specimens agreeing with the type are not known to me from New Zealand proper, but material collected from a calcareous tuff at Momoe-a-Toa, Chatham Islands, agrees in size, shape, and labiation with the species illustrated by Suess, and may be referred, temporarily at least, to *L. gravida* (Suess). The shell from Momoe-a-Toa is figured on pl. 1, Fig. 2. The dimensions are: length, 45mm.; breadth, 41mm.; thickness, 24mm.

Liothyrella kakanuiensis (F. W. Hutton 1905). (Pl. 3, Fig. 3).

1905. *Terebratella kakanuiensis* Hutton, *Trans. N.Z. Inst.*, 37 (June), p. 479, not figured.

Not *T. kakanuiensis* Thomson, *Trans. N.Z. Inst.*, 40, 1908, p. 102, pl. XIV, figs. 4 a-c (not of Hutton) = *Magella carinata* Thomson 1915.

Diagnosis: A *Liothyrella* of small size which is distinctly longer than broad (ratio 1 : ·7), is strongly inflated, and has an erect beak.

Dimensions of lectotype: Length, 10mm.; breadth, 7mm.; thickness, 6mm.

Type locality: Kakanui. Probably from the Kakanui limestone (Upper Ototaran), where it is common; but possibly (Thomson MSS.) from the underlying tuffs.

Lectotype: (Selected from two syntypes) in the Canterbury Museum.

Liothyrella landonensis J. A. Thomson 1918. (Pl. 3, Fig. 2).

1918. *Liothyrella landonensis* Thomson, in J. Park, *N.Z. Geol. Surv. Bull.* No. 20, p. 118, not figured.

Diagnosis: A *Liothyrella* like *neglecta* but slightly larger, broader, more depressed, with the greatest breadth about the middle, and a suberect beak.

Dimensions of holotype: Length, 16mm.; breadth, 14mm.; thickness, 8mm.

Type locality: Glauconitic sandstone, Landon Creek, Oamaru. Collected by G. H. Uttley.

Type in the Dominion Museum, Wellington.

Distribution: L. landonensis Thomson is the index fossil of the *landonensis*-fauna of Thomson (1926, p. 153). The association includes *Aetheia gualteri* (Morris), *Terebratulina suessi* (Hutton), *Stethothyris tapirina* (Hutton), *Rhizothyris* dwarf spp. and *Pachymagas* of the *ellipticus* series, as well as the index fossil and some other species of rarer occurrence. Thomson (1926) was inclined to regard this assemblage as a facies fauna of Upper Ototaran age, but it seems probable that it is restricted to strata which are post-Ototaran but pre-Waitakian in age. *L. landonensis* itself is recorded by Thomson (1926, p. 152, table) from the following additional localities:—

(1) Greensands, base of Maerewhenua limestone, Duntroon (J. A. Thomson coll.).

(2) Glauconitic limestone, base of Waihao limestone, quarter-mile below Waihao Forks. (Coll. J. A. Thomson).

(3) Upper part of Waihao limestone (Coll. R. S. Allan).

(4) Middle and upper part of Pareora limestone, Squire's Farm, Little Pareora River. (Coll. M. C. Gudex).

Liothyrella magna (A. Hamilton 1910). (Pl. 2, Fig. 1).

1910. *Magellania magna* Hamilton, in E. J. H. Webb, *N.Z. Geol. Surv. Bull.* No. 11 (N.S.), p. 18, not figured.

Diagnosis: A *Liothyrella* of very large size which is broader than long and relatively depressed, and in which the beak is truncated at right-angles to the length by a large, narrow, strongly labiate foramen.

Dimensions of lectotype (a dorsal valve): Length, 75mm.; breadth, 85mm.; approximate thickness of valve, 20mm.

Lectotype (selected from 8 syntypes by J. A. Thomson): A fairly well-preserved dorsal valve, with the interior filled with a tough, impure, gritty limestone which obscures the cardinalia. Preserved in the Dominion Museum, Wellington.

Type locality: On the beach south of Little Wanganui River, Kongahu S.D. (Lower Kongahu Formation).

Liothyrella neglecta (F. W. Hutton 1905). (Pl. 2, Fig. 2).

1905. *Terebratella neglecta* Hutton, *Trans. N.Z. Inst.*, 37 (June), p. 479, pl. XLVI, fig. 3.

Diagnosis: A *Liothyrella* of small size which is broadly ovate (ratio of length to breadth, 1 : ·78), depressed, and has a suberect beak.

Type locality: Curiosity Shop, Rakaia River, Canterbury.

Dimensions of lectotype: length, 11·5mm.; breadth, 9mm.; thickness, 5mm.

Lectotype (selected from four syntypes) in the Canterbury Museum.

Liothyrella neozelanica J. A. Thomson 1918. (Pl. 3, Figs. 1 and 4).

1918. *Liothyrella neozelanica* Thomson, *Austral. Ant. Exp.*, 1911-14, Scient. Repts., Ser. C., Zool., vol. IV, pt. 3 (June 1), pp. 17-19, pl. XVI, figs. 36-8; pl. XVII, figs. 51-2; pl. XVIII, figs. 61, 62, 64.

1927. *Liothyrella neozelanica* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pl. 1.

Diagnosis: A Recent *Liothyrella* very similar in shape and size to *gravida* (Suess)*, but not quite so broad and of slightly greater convexity; foramen as in *gravida,* but with a slightly shorter loop in which the descending branches diverge to a smaller degree.

Dimensions of holotype: Length, 47mm.; breadth, 42mm.; thickness, 29mm.

Type in the Dominion Museum, Wellington.

Type locality: Cook Strait, off Wellington, on a flat stone entangled on a fishing line of 200 fathoms length. Abundant.

Remarks: J. A. Thomson (1918B) has described this species very fully, and his paper should be consulted for details of the pallial sinuses, and spicules.

Fossil Distribution: L. neozelanica Thomson is not known to occur in Wanganuian or Taranakian strata, but J. A. Thomson has determined single valves of a *Liothyrella* from the shell-bed at Target Gully (Awamoan) as "*Liothyrella* cf. *neozelanica* Thomson." These were collected by Dr H. J. Finlay.

Some immature specimens collected by the writer from tufaceous greensands at Whenuataru Peninsula, Pitt Island, Chatham Islands, agree in shape with juvenile specimens of the Recent species. These records should not be accepted without confirmation.

*As interpreted by the Chatham Island material here figured, pl. 1, fig. 2.

Liothyrella oamarutica (G. Boehm 1904). (Pl. 1, Figs. 5-6).

1904. *Terebratula oamarutica* Boehm, *Zeitschr, d. Deutsch. Geol. Ges.*, Jahrg., 1904, Monatsber. Nr. 8, p. 149, taf. XV, figs. 6, 7 a-c.

Diagnosis: A *Liothyrella* of medium size which is broadly ovate (ratio of length to breadth, 1 : ·9), moderately inflated; and in which the beak is obliquely truncated by a large, broadly marginate foramen, the anterior margin of which rarely extends dorsally of the hinge-line.

Dimensions of a topotype: Length, 36mm.; breadth, 33mm.; thickness, 19mm.

Type in the Boehm collection.

Type locality: Everett's Quarry, Kakanui.

Age: Upper Ototaran.

Distribution: This species is very abundant at the type locality, and is recorded by Thomson (in MSS.) from numerous Ototaran localities near Oamaru. Dr J. Marwick and the writer collected it from calcareous tuffs at Momoe-a-Toa, Chatham Islands. The Chatham Island specimens (Pl. 1, fig. 5) agree very exactly with topotypes.

Liothyrella pulchra J. A. Thomson 1918. (Pl. 2, Figs. 6-8).

1918. *Liothyrella pulchra* Thomson, in J. Park, *N.Z. Geol. Surv. Bull.* No. 20, p. 118, not figured.

1927. *Liothyrella pulchra* Thomson, *N.Z. Board Sci. and Art,* Man. No. 7, text-fig. 25 on p. 85.

Diagnosis: A broadly ovate *Liothyrella* like *oamarutica,* but with a sulciplicate anterior commissure.

Dimensions of holotype; Length, 27mm.; breadth, 24mm.; thickness, 15mm.

Type in the Dominion Museum, Wellington.

Type locality: Calcareous tuffs, Trig. M., near Totara, Oamaru. Abundant.

Age: Lower Ototaran.

Liothyrella circularis n. sp. (Pl. 2, Fig. 3; Pl. 3, Fig. 6).

Diagnosis: A *Liothyrella* like *kakanuiensis* but subcircular in shape, and not quite so inflated.

Type locality: Everett's Quarry, Kakanui.

Dimensions of holotype: Length, 11mm.; breadth, 10mm.; thickness, 6mm.

Age: Upper Ototaran.

Remarks: L. circularis n. sp. is no doubt closely related to *L. kakanuiensis* (Hutt.) from the same locality and horizon, but the difference in shape seems to merit specific recognition even if the series is variable.

Liothyrella elongata n. sp. (Pl. 2, Fig. 4).

Diagnosis: A *Liothyrella* like *kakanuiensis* but of smaller size, and considerably more elongated (ratio of length to breadth 1 : ·65), and less inflated.

Dimensions of holotype: Length, 7mm.; breadth, 4·5mm.; thickness, 3·5mm.

Type locality: Caversham sandstone, Seacliff, near Dunedin.

Distribution: L. elongata n. sp. was collected at the type locality by Mr G. J. Williams, who also discovered it at the junction of the Caversham sandstone with the underlying greensand at Yellow Bluff, Puketeraki. The writer found it not uncommon in the Caversham sandstone at Karitane.

Liothyrella pittensis n. sp. (Pl. 1, Fig. 1).

Diagnosis: A *Liothyrella* of the general shape of *oamarutica,* but with strongly carinate beak-ridges, wide ventral palintropes, a relatively high symphytium, an erect beak, and a large foramen which is narrowly marginate and not oblique.

Dimensions of holotype: Length, 42mm.; breadth, 31mm.; thickness, 23mm.

Type locality: Calcareous tuffs, Flowerpot Harbour, Pitt Island, Chatham Islands.

Liothyrella skinneri n. sp. (Pl. 1, fig. 3).

Diagnosis: A *Liothyrella* like *oamarutica,* but more elongate (ratio of length to breadth, 1 : ·75), and with a labiate foramen.

Dimensions of holotype: Length, 40mm.; breadth, 31mm.; thickness, 23mm.

Type locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands, where it is abundant and is associated with *L. gravida* (Suess) and *L. oamarutica* (Boehm).

Remarks: The species is named in honour of Mr H. D. Skinner, the leader of the Otago Institute Expedition to the Chatham Islands.

Liothyrella thomsoni n. sp. (Pl. 2, fig. 5).

Diagnosis: A broadly elliptical depressed *Liothyrella* differing from such species as *concentrica* and *oamarutica* with which it agrees in size, in the broadly rounded hinge-line and labiate foramen.

Dimensions of holotype: Length, 38mm.; breadth, 30mm.; thickness, 17mm.

Type locality: Uppermost Mount Brown limestone (E), escarpment Weka Pass-Omihi (a single specimen).

Remarks: J. A. Thomson (after whom the species is named) noted that the genus *Liothyrella* was absent from the Weka Pass-Waipara district (1920, p. 369). This is the first record of its occurrence.

Distribution: With *L. thomsoni* I associate temporarily a *Liothyrella* n. sp. recorded by Thomson (1926, p. 151) from the Hutchinsonian greensands at Deborah. Imperfect specimens of this form in the Department of Geology, Otago University, agree in shape with the type, but are marginate or show only incipient labiation. To this species also I refer at present specimens from Band F, Milburn Quarry, Clarendon. These are usually distorted, and again the foramen is marginate. Further material may prove that more than one species is here included.

The stratigraphical range of the species of *Liothyrella* so far as it is known is shown in the following table:—

	Waiarekan.	Lower Ototaran.	Middle Ototaran.	Upper Ototaran.	Landonensis-horizon	Waitakian	Basal Hutchinsonian.	Hutchinsonian greensands.	Uppermost Mount Brown Beds.	Awamoan.	Taranakian.	Wanganuian.	Recent.
L. boehmi		*	*	*	*		*						
L. circularis				*									
L. concentrica	Horizon doubtful.												
L. elongata								?					
L. gravida	Horizon doubtful.												
L. kakanuiensis			?	*									
L. landonensis					*								
L. magna	Horizon doubtful.												
L. neglecta								? *					
L. neozelanica										?			*
L. oamarutica		*	*	*									
L. pittensis	Chatham Islands.												
L. pulchra		*											
L. skinneri	Chatham Islands.												
L. thomsoni								?	*				

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Hamilton, A., 1910. In Webb, E. J. H., *N.Z. Geol. Surv. Bull.* No. 11, p. 18.

Hutton, F. W., 1873. *Catalogue of the Tertiary Mollusca and Echinodermata of New Zealand, in the Collection of the Colonial Museum. Wellington,* xvi, 48 pp.

—— 1905. Revision of the Tertiary Brachiopoda of New Zealand. *Trans. N.Z. Inst.*, 37, pp. 474-81, pls. 45-46.

Jackson, J. W., 1918. The New Brachiopod Genus, *Liothyrella,* of Thomson. *Geol. Mag.*, Dec. 6, vol. 5, pp. 73-79.

Park, J., 1923. On the Discovery of the *Liothyrella boehmi* Greensand Band at Flume Creek, Waitaki Valley. *Trans. N.Z. Inst.*, 54, pp. 80-2.

Suess, E., 1864. Brachiopoden, in Zittel, K. A. *Novara Expedition, Geol. Theil.*, Bd. I, Abth. II, Paläontologie von Neu-Seeland, pp. 56-7, taf. IX, figs. 5a, b.

Thomson, J. A., 1916. Additions to the Knowledge of the Recent and Tertiary Brachiopoda of New Zealand and Australia. *Trans. N.Z. Inst.*, 48, pp. 41-47, pl. 1.

—— 1918A. Brachiopoda, in J. Park, *N.Z. Geol. Surv. Bull.* No. 20, pp. 117-19.

—— 1918B. Brachiopoda. *Austral. Ant. Exp. 1911-14, Sci. Rept.*, Ser. C, vol. IV, pt. 3, 76 pp., 4 pls.

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—— 1927. Brachiopod Morphology and Genera (Recent and Tertiary). *N.Z. Board Sci. and Art,* Man. No. 7, 338 pp., 2 pls.

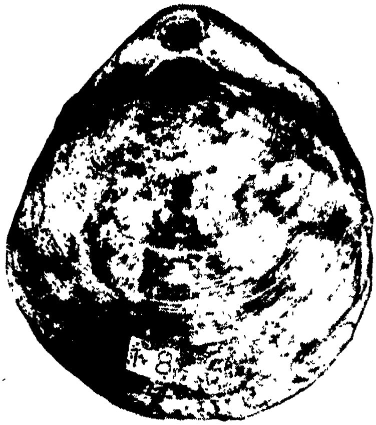
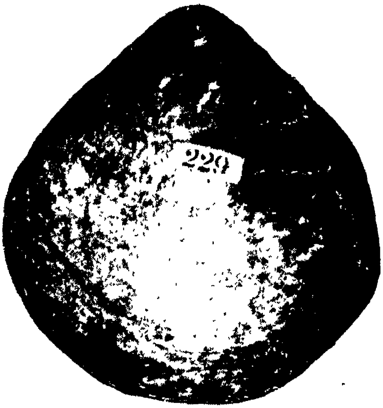


Fig. 1.



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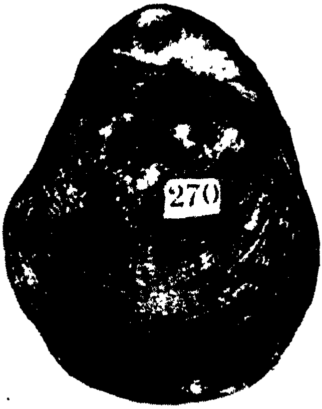

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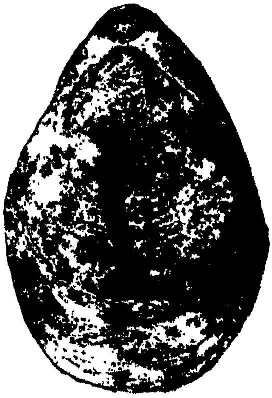

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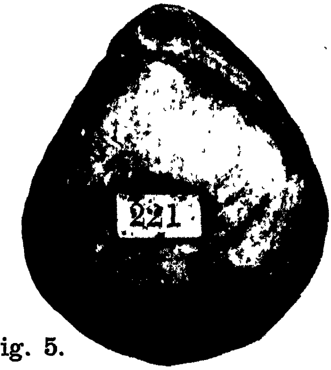

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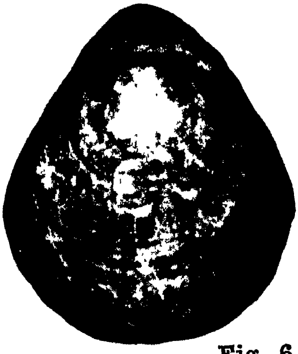
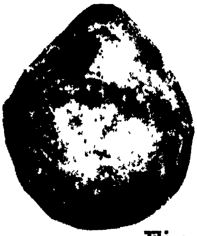


Fig. 6.

FIG. 1.—*Liothyrella pittensis* n. sp. Holotype × 1·3.
FIG. 2.—*Liothyrella gravida* (Suess) × 1·2. Chatham Islands.
FIG. 3.—*Liothyrella skinneri* n. sp. Holotype × 1·3.
FIG. 4.—*Liothyrella concentrica* (Hutton). Lectotype × 1·5.
FIG. 5.—*Liothyrella oamarutica* (Boehm). Momoe-a-Toa × 1·4.

Fig. 1.



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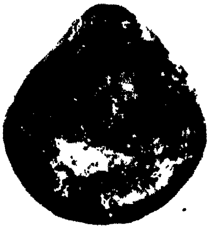

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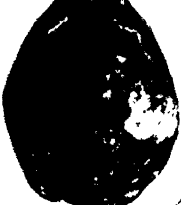

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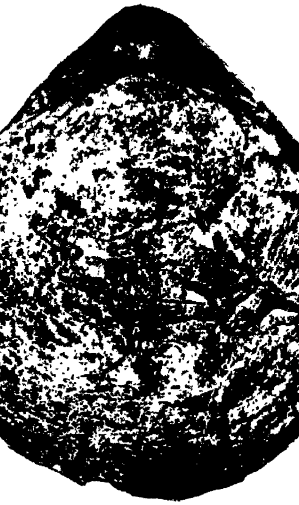

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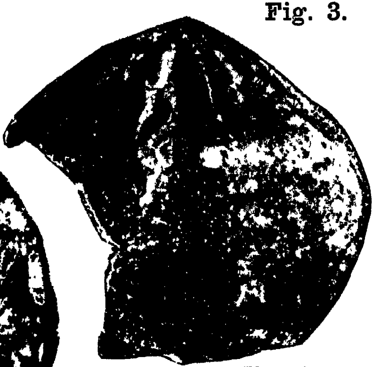
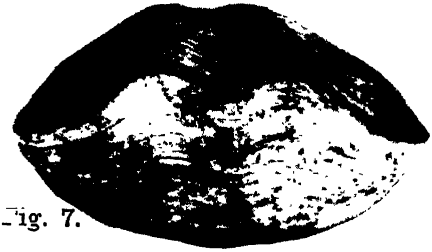


Fig. 6.



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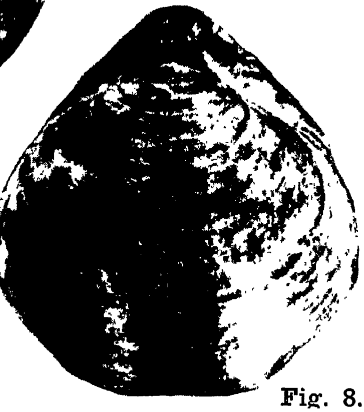
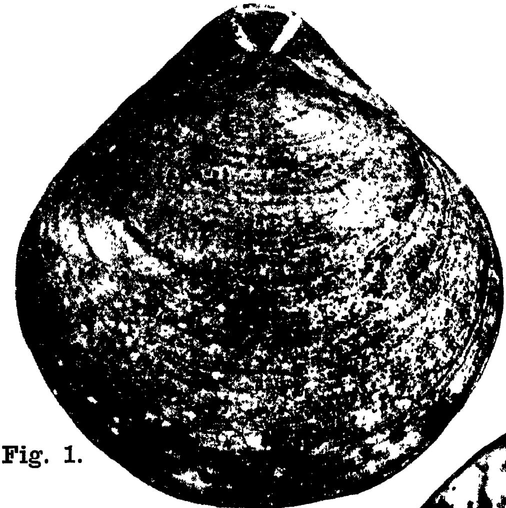


Fig. 8.

Fig. 1.—*Liothyrella magna* (Hamilton). Lectotype × ·85.
Fig. 2.—*Liothyrella neglecta* (Hutton). Lectotype × 3.
Fig. 3.—*Liothyrella circularis* n. sp. Holotype × 3.
Fig. 4.—*Liothyrella elongata* n. sp. Holotype × 4·5.
Fig. 5.—*Liothyrella thomsoni* n. sp. Holotype × 2.
Fig. 6.—*Liothyrella pulchra* Thomson. Interior of dorsal valve × approx. 1 Specimen in Dominion Museum.
7-8.—*Liothyrella pulchra* Thomson. Holoty



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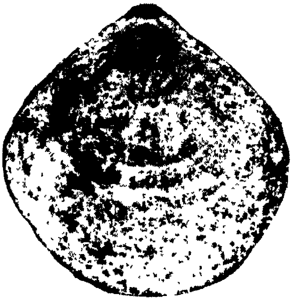

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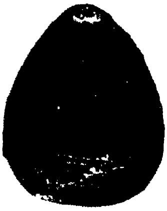

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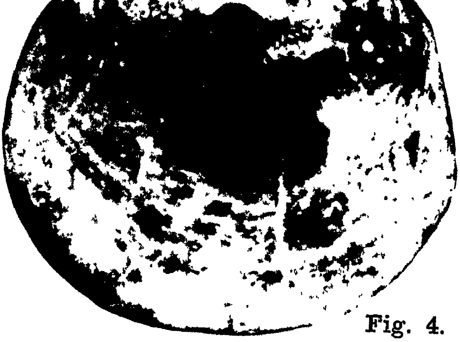

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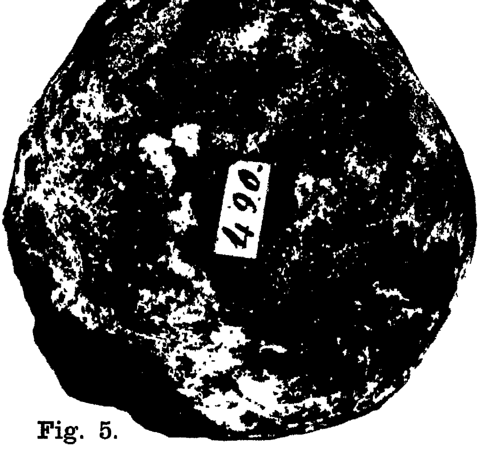

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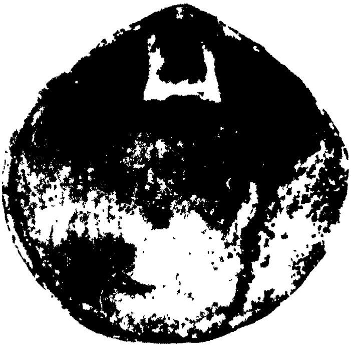

Fig. 6.

FIG. 1.—*Liothyrella neozelanica* Thomson. Holotype × 1·5.
FIG. 2.—*Liothyrella landonensis* Thomson. Holotype × 2·6.
FIG. 3.—*Liothyrella kakanuiensis* (Hutton). Lectotype × 2·8.
FIG. 4.—*Liothyrella neozelanica* Thomson. Paratype. Interior of dorsal valve × 2.
FIG. 5.—*Liothyrella boehmi* Thomson. Holotype × 1·5.
[illegible]

Tertiary Brachiopoda from the Chatham Islands, New Zealand.

[With 3 Plates.]

By R. S. ALLAN, M.Sc. (N.Z.), Ph.D. (Cantab.), F.G.S., National Research Scholar.

[*Read before the Otago Institute, 11th November, 1930.*]

INTRODUCTION.

THE material upon which this report is based was collected during the Otago Institute Expedition to the Chatham Islands in 1924-25. Fossils from Tioriori, Momoe-a-Toa, and Red Bluff were collected by Dr J. Marwick and the writer; those from other localities by the writer alone. It is a pleasure to express appreciation of Dr Marwick's valuable help in the field.

The Tertiary species proved very interesting, and their study adds considerably to our knowledge of the brachiopoda in the New Zealand region. Generically the agreement with New Zealand proper is strong, but the majority of the species are new. The commonest genera are *Liothyrella, Terebratella, Pachymagas,* and *Terebratulina. Neothyris, Magella,* and *Neobouchardia* are each represented by a single species. Of special interest is the relative abundance of the Dallininae represented by two new species of *Campages,* and a new genus. *Campages* had been recorded from New Zealand by J. A. Thomson, but the Chatham Islands species are the first to be described. A fossil *Crania,* to be described later, the first from New Zealand, is also noteworthy.

In view of the close generic agreement between the New Zealand and Chatham Island forms, it is rather surprising to note the absence from the Chatham Islands of such common mainland genera as *Tegulorhynchia, Rhizothyris, Waiparia, Stethothyris, Aetheia,* and *Magadina.* It may be noted, however, that *Tegulorhynchia nigricans* (Sowerby) is common as a Recent shell at the Chatham Islands.

The affinities between the two faunas make it certain that during the period represented by the fossiliferous strata of the Chatham Islands, that locality was never separated from New Zealand by a deep sea.

No Tertiary Brachiopoda have hitherto been described from the Chatham Islands, but Dieseldorff (1901, pp. 55-6) recorded *Waldheimia lenticularis* Desh., and *Terebratula* sp. from Flowerpot Harbour, Pitt Island.

The Chatham Islands Brachiopoda were sent by the writer to the late J. A. Thomson for study, but failing health, and more pressing work, prevented him from preparing a report. I must acknowledge his kindness in naming generically the species from Momoe-a-Toa and Tioriori. I have also to thank Mr W. R. B. Oliver and Dr J. Marwick for the care with which they returned the material to me. My thanks are due to Professor W. N. Benson for allowing me working facilities in his department. For permission to publish, I thank the Hon. the Minister for the Department of Scientific and Industrial Research.

DESCRIPTION OF SPECIES.

TEREBRATULINA A. d'Orbigny 1847.

1847. *Terebratulina* d'Orbigny, *Ann. Sci. Nat.*, ser. 3, vol. 8, Zool., p. 249.
1927. *Terebratulina* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 186-188.

Type (by original designation) *Anomia caput-serpentis* Linnaeus, 1767, *Syst. Nat.*, ed. 12, p. 1153 (not of Linnaeus, 1758, *Syst. Nat.*, ed. 10, p. 703) = *Anomia retusa* Linnaeus, 1758, p. 701. Recent.

Terebratulina suessi (F. W. Hutton 1873). (Pl. 4, Fig. 1).

1864. *Terebratulina* sp. ind., E. Suess, in K. A. Zittel, *Novara Exped., Geol. Theil.*, Bd. I, Abth. II, Paläont. von Neu-Seeland, p. 57, Taf. IX, figs. 6 a-c.
1873. *Terebratella suessi* F. W. Hutton, *Cat. Tert. Moll. Ech. N.Z.* p. 37, not figured.
1904. *Terebratulina oamarutica* G. Boehm, *Zeitsch. d. Deutsch. geol. Gesell. Mitteil*, Bd. 56, pp. 148-9, Taf. XV, figs. 1-5.
1905. *Terebratulina suessi* Hutton, *Trans. N.Z. Inst.*, 37, p. 474, not figured.
1920. *Terebratulina suessi* Hutt., J. A. Thomson, *Trans. N.Z. Inst.*, 52, p. 369, not figured.

Chatham Island localities: (1) Tioriori, in tufaceous greensands. (Rare). (2) Tufaceous limestone, Flowerpot Harbour, Pitt Island. (Very common). (3) Tufaceous greensands, Whenuataru Peninsula, Pitt Island (two specimens).

Remarks: T. suessi (Hutton) is very common and widespread in the middle Tertiary strata of New Zealand, and according to Thomson *(N.Z. Journ. Sci. and Techn.,* VIII (3), 1926, p. 153), ranges from the Waiarekan to the Hutchinsonian.

I am at present unable to decide whether the New Zealand Terebratulinas belong to a single variable species of long range, or to several species which are at present confused under the name *suessi* (Hutton).

Hutton (1905), and, according to J. Park (*N.Z. Geol. Surv. Bull.* No. 20, 1918, p. 37, footnote) J. A. Thomson, both consider that *T. oamarutica* Boehm is a synonym of *T. suessi* (Hutton). It is well known, however, that Thomson has, since 1918, considerably modified his earlier conception of both genera and species. If these species are identical it becomes necessary to explain why at Everett's Quarry, near Kakanui (the type locality of Boehm's species), where *T. oamarutica* Boehm occurs in great abundance, the individual length of specimens rarely exceeds 10 mms., while elsewhere *T. suessi* (Hutton) reaches a length of 20-27 mms.

I incline to the view that more than one species exists on the mainland, but further material is required before this can be demonstrated. In the meantime, I refer the Chatham Islands material from the localities noted to *T. suessi* (Hutton). The type locality of Hutton's species is the Curiosity Shop, Rakaia River, Canterbury. A single individual from Momoe-a-Toa is proposed as the type of a new species, described below.

Terebratulina ellisoni n. sp. (Pl. 4, Fig. 3).

Shell of moderate size for the genus, broadly ovate, with a wide, prominent beak, and large foramen. Dorsal valve with evenly rounded sides and front, and a pointed umbo, on either side of which is a depressed triangular area. Ventral valve rounded in front, then with straight, tapering sides. Beak ridges rounded, separating off wide, concave palintropes. Hinge-line broad and straight. Foramen very large, submesothyrid. Deltidial plates small, disjunct. Beak broadly truncate.

The ventral valve is strongly convex, the dorsal less so. Anterior commissure rectimarginate. Ornamentation of numerous fine costae, increasing mainly by bifurcation.

Dimensions of holotype: Length, 13mm.; breadth, 10mm.; thickness, 55mm.

Type locality: Calcareous tuff, Momoe-a-Toa, Chatham Islands.

Remarks: This species is named in compliment to Dr E. Ellison, Resident Magistrate and Health Officer at the Chatham Islands during our Expedition.

Affinities: Dr J. A. Thomson, to whom this specimen was sent for examination, remarked, " A very distinct new species." It is quite unlike anything I know from the mainland.

LIOTHYRELLA J. A. Thomson 1916.

1932. *Liothyrella* R. S. Allan, *Trans. N.Z. Inst.*, 63.

Remarks: The species of *Liothyrella* from the Chatham Islands are described by the writer in this volume, pp. 1-10. The species are:—

1. *Liothyrella oamarutica* (Boehm). Momoe-a-Toa. Pl. 6, fig. 4.
2. *Liothyrella gravida* (Suess). Momoe-a-Toa. Pl. 6, fig. 1.
3. *Liothyrella skinneri* Allan. Momoe-a-Toa. Pl. 6, fig. 5.
4. *Liothyrella pittensis* Allan. Flowerpot Harbour. Pl. 6, fig. 2.
5. *Liothyrella neozelanica* Thomson. ?? Juveniles. Whenuataru Peninsula.

CAMPAGES C. Hedley 1905.

1905. *Campages* Hedley, *Rec. Austral. Mus.*, VI (2) (Sept. 15), p. 43.
1927. *Campages* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 249-51.

Type (by monotypy) *Campages furcifera* Hedley 1905, pp. 43-4, figs. 5-6. Recent.

Campages chathamensis n. sp. (Pl. 5, Fig. 5).

Shell trigonal, widest in front, beak bluntly rounded, hinge-line narrow, strongly curved, sides first diverging, very slightly curved, then nearly straight, front margin abruptly truncated.

Dorsal valve convex, flattened in the middle of the front, ventral valve strongly convex, bicarinate. Anterior commissure strongly intraplicate. Beak suberect, short, not produced dorsally of the hinge-line. Beak ridges indistinct. Foramen large, permesothyrid (this point is difficult to decide), narrowly marginate. Length of holotype, 17mm.; breadth, 13mm.; thickness, 11mm. Hinge-teeth rather small, without dental plates or swollen supports.

Cardinalia weak, with a narrow excavated hinge-plate, dental sockets rather prominent. Crura diverging little from the septal plane. Septum very long, high posteriorly, but descending to the floor of the shell at about half the length, thickened, and excavated above at its junction with the hinge-plate. Cardinal process small, projecting from the umbo, transverse, excavated in the middle. Loop not preserved.

Type locality: Greensands, Tioriori, Chatham Islands, where the species is very abundant.

Remarks: The shells are very fragile, and it is difficult to get an absolutely complete specimen. The holotype has part of the dorsal valve broken. I have not been able to develop a loop, although many specimens were available. The cardinalia and septum tend to be very powdery.

Affinities: This is the first species of *Campages*, and the first member of the Dallininae, to be described from the New Zealand area. Thomson (1927, p. 250) has, however, recorded the genus. In a private letter he informed me that he had more than one undescribed species from the Oamaruian of New Zealand; he also stated that the Chatham Island shell was specifically distinct from the mainland forms.

Only three species of *Campages* have hitherto been described, and all are recent species. They are (a) *C. furcifera* Hedley, the genotype, from 11 fathoms, off the coast of New South Wales; (b) *C. asthenia* Dall (1920, p. 365, not figured), from off the Philippines and Borneo, 318-347 fathoms; and (c) *C. basilanica* Dall (1920, pp. 365-6, not figured) from Japan and Korea, 50-361 fathoms, China Sea, Philippines, and Celebes, 68-700 fathoms. Fossil representatives are unknown outside the New Zealand-Chatham Islands area. *C. chathamensis* n. sp. appears to be distinct from all the Recent species known.

Campages toaensis n. sp. (Pl. 5, Fig. 4).

Shell similar in general appearance to *Campages chathamensis* n. sp., but larger, more elongate, and broadly instead of acutely intraplicate. Dimensions of holotype (a slightly distorted shell). Length, 26mm.; breadth, 16mm.; thickness 15mm.

Type locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands (3 specimens).

Chathamithyris traversi gen. et sp. nov. (Pl. 4, Figs. 4 and 6).

Shell small, pear-shaped, laterally compressed, smooth, and strongly biconvex. Beak prominent, suberect. Beak-ridges not prominent. Foramen large, mesothyrid, attrite. Symphytium rather low, raised in the middle. Ornamentation of indistinct growth-lines. Punctae small and dense. Anterior commissure incipiently sulcate. Hinge-line strongly curved.

Cardinalia weak, lamellar, hinge-plates excavate, and supported by the septum. The latter is low and extends about two-thirds the length of the valve. Loop terebrataliform or early dalliniform. The descending branches are close together and subparallel to the septum, to which they appear to be attached. Anteriorly the descending branches are strongly reflected and attached to a large, broadly lamellar ring which is free from the septum. The whole loop extends rather more than half the length of the valve. Interval of ventral valve unknown.

Length of holotype, 10mm.; breadth, 5·5mm.; thickness, 6·5mm.

Type locality: Waikaripi, south of the wireless station, Chatham Islands, near the base of the tufaceous limestone.

Material: Three specimens, including the perfect holotype, and two dorsal valves (one prepared to show the loop). One dorsal valve shows the median septum, and half the hinge; the other shows a complete loop which is coated in secondary calcite to such an extent that it is difficult to be certain whether or not the descending branches are attached to the septum.

Remarks: This interesting species agrees closely in general appearance with *Pirothyris vercoi* (Blochmann) (see Thomson, 1927, p. 280, fig. 94), but is incipiently sulcate, not uniplicate, while the loop characters place the Chatham Island shell in the Dallininae.

Of this sub-family, *Diestothyris, Terebratalia, Dallinella,* and *Japanithyris* have a terebrataliform loop, while *Macandrevia, Coptothyris,* and *Dallina* have attained the dalliniform stage.

Dallinella differs from *Chathamithyris* by the possession of a permesothyrid foramen and of narrowly intraplicate folding. *Coptothyris* differs in being multiplicate, permesothyrid, and of transverse shape. *Terebratalia* differs in having an incomplete foramen, a transverse shape, is usually multiplicate, and has strong cardinalia. *Diestothyris* differs in having an incomplete, submesothyrid, foramen, and large, widely-spaced punctae. *Japanithyris* and *Dallina* differ in being broadly sulcate to intraplicate, and in having coarse punctation. *Macandrevia* has an open delthyrium, and no septum in adult shells.

Complete details of these genera will be found in Thomson *(N.Z. Board Sci. and Art,* Man. No. 7, 1927, pp. 231-255).

NEOBOUCHARDIA J. A. Thomson 1927.

N.Z Board Sci. and Art, Man. No. 7, pp. 2 and 270-1.

Type (by monotypy): *Bouchardia minima* Thomson, 1918.

Neobouchardia minima (J. A. Thomson 1918).

1918. *Bouchardia minima* Thomson, *Geol. Mag.*, Dec. 6, vol. 5 (June), pp. 260-1, fig. 1 a-c on p. 260.

1927. *Neobouchardia minima* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 270-1, text-fig. 89 on p. 270.

Remarks: A single, well-preserved, complete specimen of a *Neobouchardia* closely allied to, and probably identical with, the genotype, was found in the soft bryozoan limestone (Te Whanga Series) at Whenuataru Peninsula, Pitt Island.

The Chatham Islands specimen differs from *N. minima* (Th.) in some respects. It is considerably larger, slightly more produced anteriorly, and the beak is more prominent. The Chatham Islands fossil is at a slightly higher stage of evolution as regards elongation, and, therefore, should, perhaps, be the type of a new species.

I prefer to leave it under *minima* until further material is available.

B. minima (Thomson) was originally described from the base of the Main Mount Brown Limestone, in the cuesta between Mount Brown and the Waipara River, North Canterbury. It is locally abundant in the Main Mount Brown Limestone in the Weka Pass-Waipara district, and is associated with a purely Hutchinsonian brachiopod fauna. Thomson also recorded this species from the Ototaran limestone of Flat Top Hill, near Oamaru. More recently, Thomson *(N.Z. Journ. Sci. and Techn.*, VIII (3), 1926, p. 151) noted the occurrence of this species from the Kakanui greensands of Hutchinsonian age.

This distribution on the mainland suggests an Ototaran-Hutchinsonian age from the Te Whanga limestones of the Chatham Islands.

PACHYMAGAS von. Ihering 1903.

1903. *Pachymagas* von Ihering, *An. Mus. Nac. Buenos Aires*, ser. 3A, vol. 2, p. 332.

1920. *Pachymagas* Thomson, *Trans. N.Z. Inst.*, 52, p. 374.

1927. *Pachymagas* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 286-8.

Type: Terebratella (Pachymagas) tehuelcha von Ihering, 1903, p. 332, figs. 7a-b, Pliocene, Patagonia.

Four species are herein referred to the genus *Pachymagas* because of their general resemblance to species definitely placed in that genus in New Zealand proper. It is not certain, however, that they do not belong to the related genus *Neothyris,* which differs from *Pachymagas* only in that the loop has attained the magellaniform stage of development. I was unable to prepare a loop in any of the

Chatham Island fossils placed in *Pachymagas*. They agree in having a rectimarginate anterior commissure, whereas all the New Zealand species, with the single exception of *P. marshalli* (Andrew), are definitely sulcate. The Chatham Islands species, therefore, if they are correctly placed generically, represent a regional group which has lagged behind in the development of folding, i.e., if they are of Hutchinsonian age; on the other hand, if the tuffs of Momoe-a-Toa are pre-Hutchinsonian as the Terebratulids suggest, the lack of folding is a primitive character.

Pachymagas bauckei n. sp. (Pl. 6, Fig. 3).

Shell shield-shaped, beak short, obtuse, hinge-line very broad and straight, sides first nearly straight, then gradually tapering, front produced, gently rounded. Valves only moderately convex, anterior commissure rectimarginate. Beak erect, slightly produced dorsally of the hinge-line. Beak ridges carinate. Foramen small, mesothyrid, attrite.

Length of holotype, 48mm.; breadth, 43mm.; thickness, 20mm.

Type locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands. (Rare).

Affinities: This species is similar in shape to *Rhizothyris rhizoida* (Hutton), but the mesothyrid foramen places it in *Pachymagas* (or *Neothyris*). Of the mainland species of *Pachymagas, P. bauckei* n. sp. approaches most closely in shape to *P. speighti* Thomson *(Trans. N.Z. Inst.*, LII, 1920, p. 376, pl. XXV, figs. 12-14), but differs in having an even broader hinge-line, and no anterior sulcation.

Remarks: The specific name is in compliment to William Baucke, Esq., who was born at the Chatham Islands in 1848, and was keenly interested in the natural history of his island home.

Pachymagas seymouri n. sp. (Pl. 4, Fig. 5).

Shell broadly ovate, beak rather long, hing-line narrow, strongly curved, sides broadly rounded, merging into the beak, front gently rounded, greatest breadth in front of the middle. Valves equally convex. Anterior commissure rectimarginate. Beak erect, produced dorsally of the hinge-line, beak-ridges rounded. Foramen large, mesothyrid, attrite.

Length of holotype, 48mm.; breadth, 46mm.; thickness, 22mm.

Type locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands. (Rare).

Remarks: Named in honour of Charles Seymour, Esq., of Wharekauri, to whom the expedition owes thanks for open-hearted hospitality.

Affinities: P. seymouri n. sp. recalls *P. andrewi* Thomson *(Trans. N.Z. Inst.*, 52, 1920, p. 380, pl. XXVI, figs. 1-2), but differs in having a larger foramen, a rather more strongly curved hinge-line, and an anterior commissure which is rectimarginate, not sulcate.

Pachymagas cf. **marshalli** (Andrew, 1906). (Pl. 4, Fig. 7).

Compare:—

1906. *Magellania marshalli* A. R. Andrew, *Trans. N.Z. Inst.*, 38 (June), p. 456, pl. IV, figs. 3, a, b.

1920. *Pachymagas marshalli* (Andrew) J. A. Thomson, *Trans. N.Z. Inst.*, 52, p. 375, text-fig. 7 on p. 375 (holotype).

Description: Shell circular, beak fairly short, obtuse, hinge-line broad, little curved, sides convex, front rounded, not produced. Valves moderately convex, anterior commissure nearly straight (it is lightly crushed in the figured specimen). Beak nearly erect, slightly produced dorsally of the hinge-line, foramen moderate, mesothyrid, attrite. Beak ridges sharp. Interior not investigated.

Length of Chatham Island specimen, 47mm.; breadth, 45mm.; thickness, 19mm.

Locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands.

Affinities: This specimen agrees most closely with *P. marshalli* (Andrew), and may be referred provisionally to that species. It agrees in size, convexity, shape, and simple anterior margin. The beak shows slight differences. It is erect in *marshalli*, but only nearly erect in the Chatham Islands form; also in the latter the beak is more produced dorsally of the hinge-line, and the beak ridges are more strongly carinate.

P. marshalli is an unsatisfactory species. The holotype is " poorly preserved, crushed, and somewhat distorted " (Thomson). The only topotypes I was able to collect during a recent visit to Clarendon were also unsatisfactory, being crushed, and embedded in an exceedingly tough limestone matrix.

Marshalli was described from the Clarendon limestone, Milburn Quarry, Otago. Smaller shells, agreeing in shape, have been recorded by Thomson (1920) from the Mount Somers limestone, and the greensands of Curiosity Shop, Kakanui, All Day Bay, and Three Roads. Allan (*Trans. N.Z. Inst.*, 57, 1927, p. 302) has recorded a comparable form from the Hutchinsonian sandy-clays in the Lower Waihao Valley.

Pachymagas marwicki n. sp. (Pl. 5, Fig. 3).

Shell broadly elliptical, beak short, acute, hinge-line narrow, strongly curved, sides gently convex, front rounded, greatest breadth rather in front of the middle. Valve equally convex, anterior commissure nearly straight. Beak erect, produced dorsally of the hinge-line. Foramen of moderate size, mesothyrid, attrite. Beak ridges fairly prominent.

Length of holotype, 47mm.; breadth, 41mm.; thickness, 22mm.

Type locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands.

Remarks: This is the commonest *Pachymagas* at Momoe-a-Toa. An incomplete specimen apparently referable to this species was found in a calcareous tuff at the base of Onoua Bluff, Flowerpot Harbour, Pitt Island. The species is named in compliment to my companion at the Chatham Islands, Dr J. Marwick.

Affinities: P. marwicki n. sp. is a distinct form readily separable from mainland species. It approaches most closely to *P. hectori* Thomson *(Trans. N.Z. Inst.,* 52, 1920, p. 377, pl. XXIV, figs. 10-13), but differs in shape, has a smaller foramen, a more curved hinge-line, and lacks the flat-bottomed anterior sinuation.

NEOTHYRIS H. Douville 1880.

1880. *Neothyris* Douville, *Bull. Soc. géol. France,* sér. 3, t.*vii,* pp. 274-5.
1927. *Neothyris* Thomson, *N.Z. Board Sci. and Art,* Man. No. 7, pp. 288-90.

Type (by original designation): *Terebratula lenticularis* Deshayes, 1839, *Revue Zool. Soc. Cuvierienne,* 1839, p. 359.

Neothyris thomsoni n. sp. (Pl. 5, Figs. 1-2).

Shell large, broadly elliptical, beak short, obtuse, hinge-line broad, little curved, sides first straight, then sloping gently, front rounded, greatest breadth about the anterior third. Valves strongly convex, of equal convexity. Anterior commissure rectimarginate. Beak erect, considerably produced dorsally of the hinge-line. Beak-ridges carinate, meeting the sides in an obtuse angle. Foramen small, mesothyrid, attrite. Pseudo-deltidium narrow, concave.

Length of holotype, 55mm.; breadth, 46mm.; thickness, 30mm.

Interior: (a) ventral valve: hinge-teeth strong, with a solid base, and a well marked groove on the inner side of each tooth; (b) dorsal valve: cardinalia strong, crural bases fused laterally with the socket ridges, which are strong and wide. Hinge-sockets large, wide, and deep. Septum rather short, strong, wide posteriorly, bifurcating at its junction with the inner socket ridges, tapering rapidly, of equal height for the greatest part of its length and then descending steeply to the floor of the valve. Hinge trough wide and deep. Cardinal process large, high, swollen in front, with a median ridge on its upper part, and posteriorly two wings enclosing a tunnel-like cavity of some depth. Crura plate-like, expanded above and below, giving a structure like a fish-tail. Muscle impressions strong. Loop magellaniform.

Type locality: Tufaceous greensands, Whenuataru Peninsula, Pitt Island, where the species is very abundant.

Remarks: This fine species is named in honour of the late J. A. Thomson, whose masterly studies of Tertiary and Recent Brachiopoda are an inspiration to those who follow in his footsteps.

Affinities: N. thomsoni n. sp. is undoubtedly to be compared with the Recent *N. lenticularis* (Deshayes). The former has a broader hinge-line, the beak is erect, not curved, and less produced, and the foramen is smaller. The anterior commissure is practically rectimarginate, while in *N. lenticularis* there is a definite, if shallow, sulcation. In thin-shelled specimens of *N. thomsoni* the cardinal process is identical with that of *lenticularis,* but in thick-shelled specimens it is very much larger in the fossil, having a more prominent median ridge, a deeper median cavity behind, and longer lateral wings. The punctation in both species is identical, the punctae being rather large but close. *N. lenticularis* is in a more advanced evolutional stage as regards curvature of the hinge-line, incurvature of the beak, and folding. In the stage of development of the cardinal process, and in size of the foramen, however, *N. thomsoni* is more advanced than *N. lenticularis.* These facts suggest that *N. thomsoni* is a geographical variant of the *lenticularis* series, and not a direct ancestor of *lenticularis* itself.

Among the numerous, well preserved specimens from the type locality is a single individual which differs from the holotype in possessing an incurved beak, and a subcircular outline (thus approaching *N. lenticularis*), but it has an even broader hinge-line than the holotype of *N. thomsoni. N. lenticularis,* as a fossil, is confined to the Wanganuian, and *N. thomsoni* is so closely related that it, too, must indicate a Wanganuian age for the horizon from which it is derived.

MAGELLA J. A. Thomson 1915.

1915. *Magella* Thomson, *Trans. N.Z. Inst.*, 47 (July 12), pp. 396-7.

1927. *Magella* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 290-1.

Type (by original designation) *Magella carinata* Thomson 1915 = *Terebratella kakanuiensis* Thomson 1908, *Trans. N.Z. Inst.*, 40, p. 102, pl. XIV, figs. 4 a-c (not of Hutton).

Magella pittensis n. sp. (Pl. 5, Fig. 7).

Shell externally identical with a medium sized specimen of *Terebratella inconspicua* (Sowerby), but without incipient multicostation. Loop magelliform.

Length of holotype, 11·5 mm.; breadth, 11mm.; thickness, 6·5mm.

Type locality: Calcareous tuffs, Onoua Bluff, Pitt Island. Also: calcareous tuffs, Flowerpot Harbour, Pitt Island. A single, worn, dorsal valve of either this species or a true *Terebratella inconspicua* (Sow.) was found in the greensands at Whenuataru Peninsula, Pitt Island.

Affinities: M. pittensis n. sp. differs from the genotype in being subcircular instead of ovate. S. S. Buckman (*Wissensch. Ergebn. Schwed. Südpolar Expd.*, 1901-3, Bd. III, Lief. 7, 1910, pp. 18-20), described two species of *Magasella* which Thomson (1927) referred to *Magella. M. australis* (Buckman) (1910, pp. 19-20, pl. I, figs. 14-16; pl. III, figs. 3a, 3b) from the Pecten Conglomerate, Cockburn Island, off Graham Land, Antarctica, is an ovate species, and hence readily distinguished from *pittensis*. *Magella antarctica* (Buckman) (1910, p. 18, pl. I, fig. 17) from the Glauconitic Bank (Miocene-Oligocene), Cockburn Island, agrees closely in shape, but differs in being incipiently multicostate, a feature in which it agrees with old age specimens of *T. inconspicua*. Buckman (1910, p. 18) suggested tentatively that *M. antarctica* might be described as the magaselliform (i.e., magelliform) ancestor of *T. rubicunda* (i.e., *T. inconspicua*), but Thomson argued " one would hardly expect even incipient multicostation, such as *M. antarctica* shows, on a Miocene ancestor of *T. rubicunda.*" (1915, p. 397, footnote). On both morphological and geographical grounds *M. pittensis* is a more probable direct ancestor of *Terebratella inconspicua* (Sow.).

TEREBRATELLA A. d'Orbigny 1847.

1847. *Terebratella* d'Orbigny, *C. R. Acad. Sci.* 25, p. 229.
1927. *Terebratella* Thomson, *N.Z. Board Sci. and Art*, Man. No. 7, pp. 292-4.

Type: Terebratula chilensis Broderip 1833, *Trans. Zool. Soc. (London)*, I, p. 141, pl. 22, fig. 1 = *Anomia dorsata* Gmelin 1790, *Syst. Nat.*, ed. 13, I, p. 3348. Oligocene to Recent, South America.

Terebratella finlayi n. sp. (Pl. 5, fig. 6).

Shell small, broadly ovate, smooth, featureless. Beak suberect, acute. Beak ridges not prominent. Foramen submesothyrid but nearly mesothyrid, rather large. Valves of about equal convexity. Sides rounded, front squarely truncated. Anterior commissure rectimarginate, with no sign of incipient multicostation. Deltidial plates long and narrow, disjunct. Ornamentation of rather widely spaced growth lines. Punctae small and dense.

Dimensions of holotype: Length, 7mm.; breadth, 5mm.; thickness, 3mm.

Type locality: Tufaceous greensands, Tioriori, Chatham Islands (2 specimens).

Remarks: This species is named after my friend, Dr H. J. Finlay, who detected the material in the matrix attached to specimens of *Notostrea tarda* (Hutton) given him by the writer. The species is not likely to be confused with any other member of the genus described from New Zealand.

Terebratella morioria n. sp. (Pl. 4, Fig. 2).

Shell subcircular, beak prominent, acute, hinge-line little curved, sides arched, front rounded. Ventral valve strongly convex, with a pronounced median fold; dorsal valve less convex, with a moderately deep, rapidly tapering sulcus. Anterior commissure sulcate. Beak nearly straight, beak-ridges not strongly carinate, merging into the sides. Foramen very large, submesothyrid, telate. Deltidial plates, small, disjunct. Ornamentation alternate multicostate. Dorsal valve with 14-15 stout, wide, rounded costae, two of which occupy the floor of the sulcus. Costae of greater width than the interspaces. Ventral valve with three costae on the fold. Increase of costae by bifurcation and interpolation. Punctae small and close. Interior unknown.

Length of holotype, 13mm.; breadth, 12mm.; thickness, 5·5mm.

Type locality: Calcareous tuffs, Momoe-a-Toa, Chatham Islands (a single specimen).

Remarks: The late Dr Thomson remarked of this form, "Probably new, but resembles the young of *T. radiata* Hutton." *T. radiata* Hutton was described in 1887[1], from the tuffs and greensands, Broken River, Trelissick Basin, and was figured by Hutton in 1905[2].

I have not handled specimens of Hutton's species, which is indifferently illustrated. Hutton (1905) gave the following dimensions: Length, 13mm.; width, 12mm.; thickness, 8-10mm.; and recorded about 18 ribs on the ventral valve. It is clear, therefore, that *T. radiata* is a much more convex shell, and has more costae in shells of the same size. If one may judge from Hutton's figures, the foramen of *T. radiata* is considerably smaller than that of *T. morioria* n. sp. The dorsal sulcus, also, would appear to be more deeply excavated in the mainland species. There is no other Tertiary species with which *T. morioria* might be confused.

Terebratella cf. **sanguinea** (Leach 1814).

Compare:—

1874. *Terebratula sanguinea* Leach, *Zool. Misc.*, p. 76, tab. XXXIII.

1887. *Terebratella cruenta* T. Davidson, *Trans. Linn. Soc. London*, Ser. 2, Zool., vol. IV, pt. 2, pp. 87-9, pl. XIV, figs. 1-8.

1918. *Terebratella sanguinea* (Leach) J. A. Thomson, *Austral. Ant. Exp.*, 1911-14, Scient. Repts., Ser. C, vol. IV, pt. 3, p. 31, not figured.

A single, well-preserved individual, from the tufaceous greensands, Whenuataru Peninsula, Pitt Island, appears to belong to this Recent and Wanganuian species. The Chatham specimen is probably not adult, being only 14mm. in length. When compared with Recent specimens of the same size it agrees in shape, but shows a more prominent sulcation which, moreover, is of earlier inception. The costae show no sign of bifurcation. It is possible, therefore, that the Chatham form may prove to be a distinct but closely related species. Further material is needed to settle this point.

Terebratella or **Magella** n. sp. (?).

The brachiopoda from the Te Whanga bryozoan limestones are very rare. For this reason I notice a single slightly imperfect specimen from this horizon at Whenuataru Peninsula, Pitt Island.

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[1] *Trans. N.Z. Inst.*, 19 (May), 1887, p. 406, footnote.

[2] *Trans. N.Z. Inst.*, 37, 1905, pp. 477-8, pl. XLVI, fig. 2.

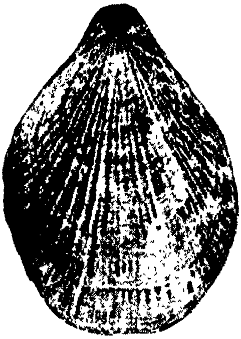

Fig. 1.

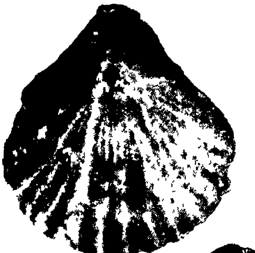

Fig. 2.

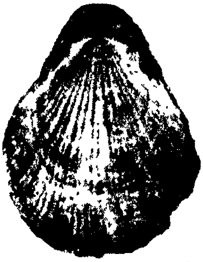

Fig. 3.

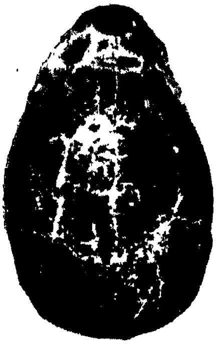

Fig. 4.

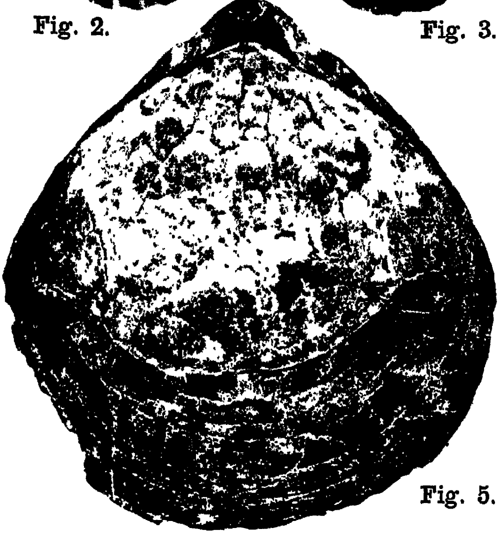

Fig. 5.

Fig. 6.

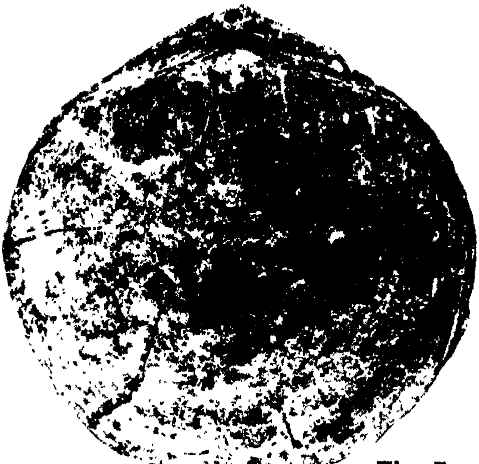

Fig. 7.

FIG. 1.—*Terebratulina suessi* (Hutton). × 2·7.
FIG. 2.—*Terebratella morioria* n. sp. Holotype, × 2·7.
FIG. 3.—*Terebratulina ellisoni* n. sp. Holotype, × 2·7
FIGS. 4 and 6.—*Chathamithyris traversi* gen. et. sp. nov. Holotype, × 4·6.
FIG. 5.—*Pachymagas seymouri* n. sp. Holotype, × 1·5.
FIG. 7.—*Pachymagas* cf. *marshalli* (Andrew). × 1·5.

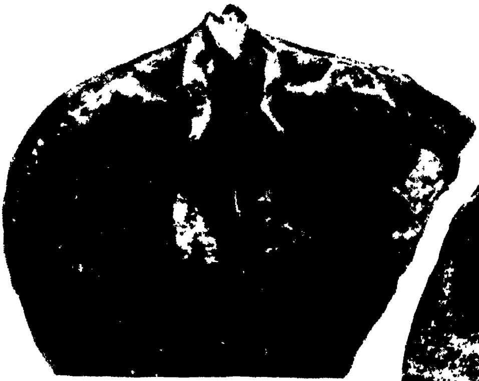

Fig. 1.

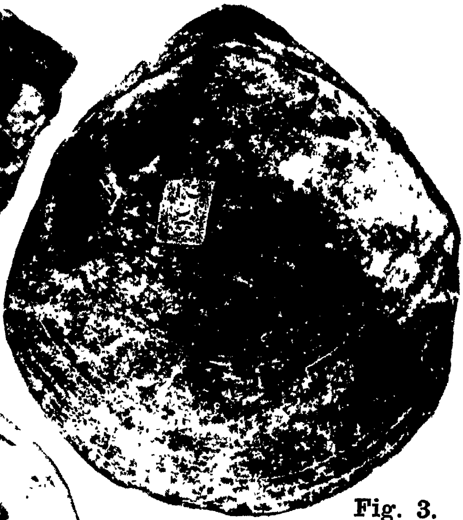

Fig. 3.

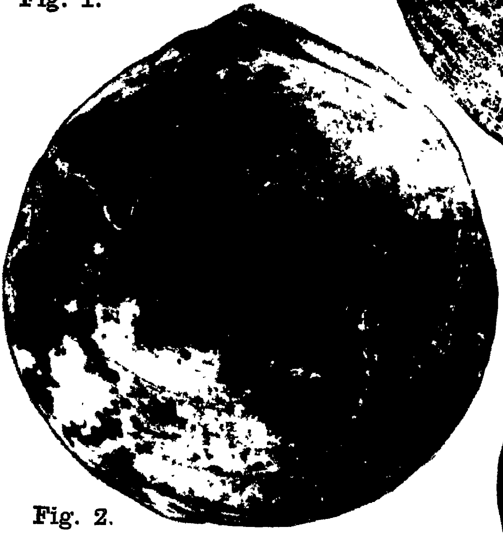

Fig. 2.

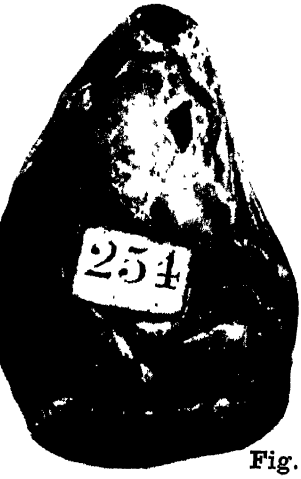

Fig. 4.

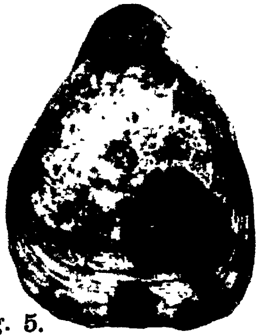

Fig. 5.

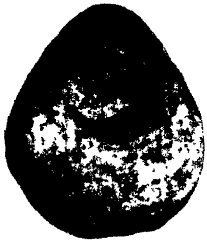

Fig. 6.

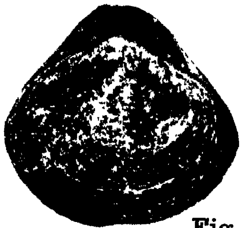

Fig. 7.

FIG. 1.—*Neothyris thomsoni* n. sp. Interior of dorsal valve × 1.3.
FIG. 2.—*Neothyris thomsoni* n. sp. Holotype, × 1.3.
FIG. 3.—*Pachymagas marwicki* n. sp. Holotype, × 1.45.
FIG. 4.—*Campages toaensis* n. sp. Holotype, × 2.5.
FIG. 5.—*Campages chathamensis* n. sp. Holotype, × 2.6.
FIG. 6.—*Terebratella finlayi* n. sp. Holotype, × 4.5.
FIG. 7.—*Magella*

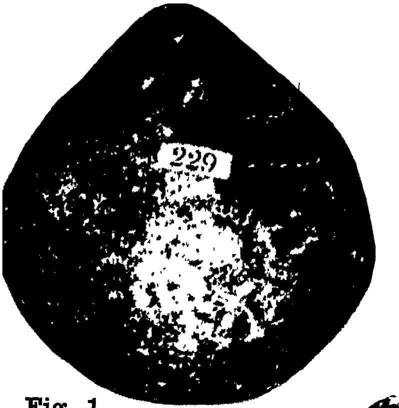

Fig. 1.

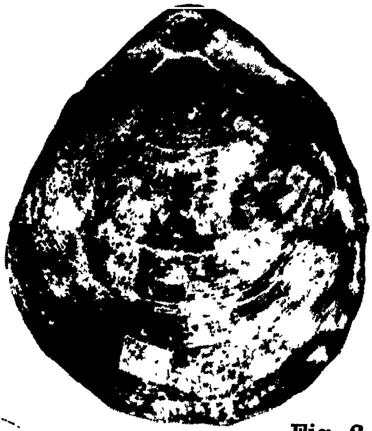

Fig. 2.

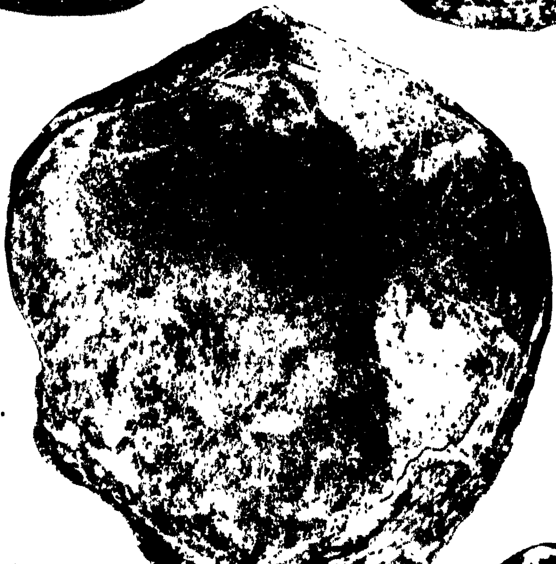

Fig. 3.

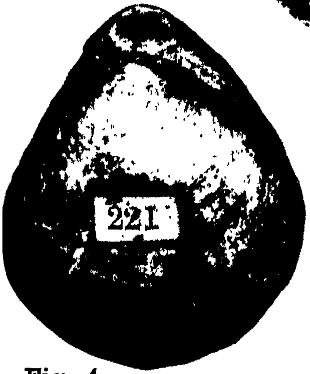

Fig. 4.

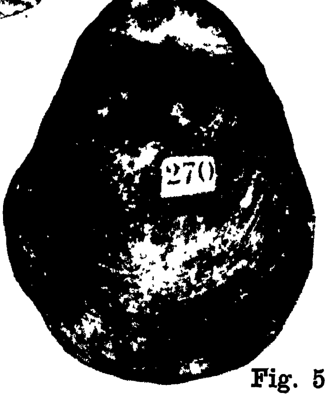

Fig. 5

FIG. 1.—*Liothyrella gravida* (Suess).
FIG. 2.—*Liothyrella pittensis* Allan. Holotype.
FIG. 3.—*Pachymagas bauckei* n. sp. Holotype × 1·7.
FIG. 4.—*Liothyrella oamarutica* (Boehm).
FIG. 5.—*Liothyrella skinneri* Allan. Holotype.

This specimen differs from *Terebratella inconspicua* (Sow.) and *Magella pittensis* n. sp. in being more elongate, and having a narrower front. The punctae, too, are apreciably more dense, and the foramen smaller, while the anterior sulcation is less pronounced. It may be that this individual is not adult.

Further material is necessary before this form can be adequately discussed and named.

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Descriptions of New Zealand Microlepidoptera.

By E. MEYRICK, B.A., F.R.S.

OECOPHORIDAE.

Trachypepla falsiloqua n. sp.

♂. 20 mm. Head ochreous-whitish, a few greyish hair scales. Palpi whitish, basal half and a subapical band of second joint grey, terminal joint ⅗, with two dark grey bands. Antennal ciliations 1½. Thorax grey, with a rough posterior crest mixed whitish. Forewings elongate, rather dilated, costa gently arched, apex pointed, termen nearly straight, oblique; whitish, partially clouded light greenish-ochreous in disc, some scattered dark brown scales; scales of basal fourth of dorsum roughened; a brown fasciate streak from base of costa above fold to ⅓, plical and first discal stigmata forming small dark bronzy-brown spots on each side of its extremity, plical slightly anterior and edged rough white scales beneath, these scales preceded by a small dark brown tuft; a spot of brownish suffusion on costa at ¼; second discal stigma rather larger, bronzy-brown, suffused bronzy-brown spots on costa rather before it and on tornus rather beyond it; an excurved dark fuscous line, gradually dilated on upper half, from costa at ⅘ to dorsum before tornus; a suffused fuscous apical spot, and two or three small greyish spots on termen: cilia whitish-ochreous, an interrupted fuscous median line. Hindwings light grey; cilia whitish-grey.

Waimarino, January *(G. V. Hudson)*; 1 ex.

TINEIDAE.

Tinea munita n. sp.

♂. 7 mm. Head light greyish-ochreous. Palpi dark fuscous, tip whitish. Antennae dark grey. Thorax light bronzy-grey. Forewings elongate, rather narrow, costa gently arched, apex obtuse, termen very obliquely rounded; rather light glossy purple, basal third somewhat sprinkled or strigulated dark fuscous; plical stigma dark fuscous; a short, rather oblique blackish streak from costa before middle, directed towards a narrow elongate black mark on dorsum; costa beyond this suffused whitish, marked first with a small blackish strigula, then with blackish spots at ⅔ and ⅚, a strigula beneath costa between these, two costal dots before apex, and a small apical spot: cilia pale greyish, basal half on costa whitish barred dark grey, at apex a grey spot, beneath apex a whitish spot between two narrow dark grey bars. Hindwings dark purple-grey; cilia grey.

Wellington, February *(G. V. Hudson)*; 1 ex.

A New Genus and Six New Species of Coleoptera.

By ALBERT E. BROOKES.

(Okauia, Matamata, Waikato.)

THE new species described in this paper are mostly forms collected by Mr E. Fairburn during a trip to Stephen and D'Urville Islands in January of this year.

The most interesting is a large weevil belonging to the genus *Phaeophanus,* taken on D'Urville Island. A most remarkable feature surrounding this genus is the distribution of four distinct species between Stephen (2), The Brothers, and D'Urville Islands, situated in close proximity to each other in Cook Strait.

Phaeophanus rugosus Broun, the genotype, is endemic on The Brothers; *P. o'connori* Broun, and *P. inornatus* Broun, on Stephen; and *P. fairburni* n. sp. described herein, on D'Urville Island. None of the above four species have been found on the mainland, which is comparatively close.

Powell, in a recent paper, " The Paryphantidae of New Zealand, their Hypothetical Ancestry " *(Rec. Auck. Inst. Mus.,* vol. 1, No. 1, pp. 17-56), has stressed the hypothesis with a somewhat elaborate map, based mainly on the geological studies of Dr Cotton, and the occurrence of *Wainuia urnula* Pfeiffer (a genus and species of the Mollusca) in the South Island, of the existence in comparatively recent times of a land-bridge connecting the North and South Islands.

In studying the members of the genus *Phaeophanus* from the several islands in Cook Strait, which are isolated flightless species, the writer is forced to quite opposite conclusions, and considers that the Cook Strait islands previously mentioned have been isolated from each other and the mainland for a very considerable period of time. If such is not the case it is extremely difficult to account for four distinct forms endemic on three small islands in such close proximity to each other and the mainland, none of the four species being found on any two of them.

Another member of the genus occurs only on the Mokohinau Islands, situated considerably more to the north, off the Auckland coast. *Phaeophanus lituratus* Broun has been described from Mount Egmont, Taranaki. I have not seen this species, but a close study of it would no doubt prove it to belong to a different genus. We have a still more remarkable instance of distribution in *Psorochroa granulata* Broun, another flightless beetle belonging to the Elateridae, evidently of archaic origin and quite common on Stephen Island (Broun gives the habitat of his type, " The Brothers, Cook Strait." This is apparently an error, as I am informed on good authority that it does not exist there.) but is to be met with again at the Chatham Islands, approximately 400 miles away. It is not known which is the true habitat of this peculiar species, which lives in rock crevices, but it is most probably Stephen Island. The writer has been informed by Mr E. S. Gourlay, of the Cawthron Institute, Nelson, who paid a recent visit to Stephen Island on research work, that this island has a peculiar formation and vegetation of its own, which stands out quite distinctly from that of the mainland. The writer is not prepared to offer any hypothesis in reference to the occurrence of the last-mentioned species at the Chathams, as the ways of Nature in her methods of distribution are multifold and ingenious.

SYSTEMATIC LIST OF THE NEW SPECIES.

Suborder ADEPHAGA.
    Superfamily Caraboidea.
        Family Carabidae.
            Subfamily Harpalinae.
                Genus *Maoritrechus* n. gen.
                    4335. *Maoritrechus rangitotoensis.*

Suborder POLYPHAGA.
    Group Clavicornia.
        Superfamily Cucujoidea.
            Family Ostomidae.
                Genus *Leperina.*
                    4336. *Leperina interrupta.*

    Group Rhynchophora.
        Superfamily Curculionoidea.
            Family Curculionidae.
                Subfamily Otiorhynchinae.
                    Genus *Inophloeus.*
                        4337. *Inophloeus quadrinodosus.*

                Subfamily Cylindrorhinae.
                    Genera *Phaeophanus, Pparchus.*
                        4338. *Phaeophanus fairburni.*
                        4339. *Pparchus gourlayi.*

                Subfamily Cryptorhynchinae.
                    Genus *Aldonus.*
                        4340. *Aldonus insularis.*

CARABIDAE.

MAORITRECHUS n. gen.

Apterous. Labrum transverse, broadly emarginate, setose. Antennae filiform, joints elongate-oval, subcylindrical, setose, 2nd and 3rd joints narrower than basal, 4th shortest, 5th to 10th about equal, terminal slightly longer. Eyes very small, coarsely facetted. Mandibles moderately long, left conically broadened in the centre, right with a subquadrate process acutely produced inwardly at its anterior angle. Femora stout, tibia slender, anterior slightly flexuous, deeply and broadly emarginate inwardly near the extremity, intermediate and posterior straight, gradually thickened to base of tarsi, tarsi setose, basal joint subquadrate, 2nd transverse, about half the length of basal, 3rd small, 4th bilobed, about same length as preceding, 5th long, claws simple. The 1st and 2nd joints of the anterior tarsi of the male are produced inwardly and to the front. Mentum bisetose, bisinuate, and slightly roundly produced medially. Maxillary palpi with basal joint small, 2nd broad, 3rd increasing in width apically, rather longer than preceding one, terminal about same length as penultimate, gradualy tapering, rounded apically. The submentum bordered by a curved ridge. Anterior coxae separated by a small, flat, low, impressed prosternal process, intermediate not distantly, and posterior well separated. Mesosternum curvidly triangular, grooved along sides and centre, the latter ending in a depression between the posterior coxal cavities, its process rounded in front and reaching a little beyond intermediate coxae. Metasternum convex, smooth. Genotype *Maoritrechus rangitotoensis* n. sp.

4335. **Maoritrechus rangitotoensis** n. sp.

Fulvo-castaneous, nitid, legs and antennae fulvus, elytra costate, labrum with six setigerous punctures.

Head deeply furrowed on each side of the middle, furrows curved outwardly and descending underneath to gullar, where they end in two punctiform depressions. Ocular areas inflated, connected dorsally by a fine groove, near the base of mandibles there is a small subcircular depression and a small tubercule on the lower lateral edge. Ocular carina short and curved, extending from antennal insertion to front of eyes, there are three not very distinct impressions in a line with back of eyes. Thorax as broad as long, widest before the middle, gradually curved posteriorly, sides margined, a little explanate, apex almost truncate, front angles produced, base truncate, hind angles slightly oblique, almost rectangular, frontal and basal impressions transverse, connected by a well defined median groove. Elytra flatly convex, with four well defined costae interrupted with punctiform impressions, striae impunctate, sutural interstices with microscopic oblique and transverse sculpture, sides gradually curved and narrowed to width of thorax, margined, lateral channels with punctures and irregular impressions, apices broadly rounded. Underside shining, basal ventral segment triangular, twice as long as 2nd and 3rd, 4th a little longer than preceding, each with a setigerous puncture on each side of the middle.

Holotype: ♂. Length, 2·75 mm.; breadth, 1 mm. In author's collection.

Allotype: ♀. Length, 2·75 mm.; breadth, 1 mm. In author's collection. Similar to male, anterior tarsi not dilated, last ventral segment bipunctate.

Material: Four specimens of this interesting, wingless beetle were taken by the author on July 4, 1920, and held back from previous papers for want of allied material for comparison.

Locality.—Rangitoto Island, Hauraki Gulf, taken under decaying Zostera, well below high-water mark, as the tide fell.

Remarks.—This species is a member of the old Subfamily Pogoninae, now reduced to a tribe; it has no near allies among the New Zealand Coleoptera. Superficially it has a striking resemblance to some species of *Anophtalmus,* a genus of blind cave beetles confined chiefly to Europe, with a few species inhabiting North America.

OSTOMIDAE.

Leperina Erichson, 1844. *Germar Zeitschr. Entom.*, 5, p. 453.

4336. **Leperina interrupta** n. sp.

Head and discal portion of thorax dark brown, elytra, sides of thorax, antennae, and palpi reddish-brown.

Head transversely depressed and emarginate in front, obliquely narrowed from the eyes forward, labrum emarginate, whole surface covered with moderately large punctures. Eyes oblique. Thorax one-third broader than its greatest length, almost truncate in front with the angles narrowly roundly produced, hind angles rectangular, widest about middle, sides obliquely narrowed towards front and base, explanate, its whole surface more or less shining, punctated, a narrow space on the centre with punctures more distant. Elytra two and one-third times as long and as wide as middle of thorax is, at base, which is wider than that of thorax, shoulders almost square, very little rounded, sides finely margined, parallel to well behind hind thighs, then gradually rounded to apices, lateral areas broadly perpendicularly channelled, each elytron has seven narrow ridges on top interrupted with punctures, also three in the lateral channels more broken up owing to closer punctation, all the ridges have a greenish tinge, interstices with light and dark brown scales, markings dark and interrupted, there is a narrow transverse band on top of the posterior slope extending to top of lateral channels, outer ends rounded for a short distance forward, then inwards and again a very little forward, also an inverted similar mark immediately above, on the right elytron this mark forms an interrupted S, on the left it is reversed, there are also several dark marks on the sides and two on the posterior slope close to the suture, also an obsolete oblique one near the shoulders. Underside dark, outer edges reddish-brown, the whole surface punctate, coarse in front, gradually becoming finer towards last ventral segment, abdomen deeply covered by elytra.

Holotype: ♂. Length, 10 mm.; breadth, 4 mm. In author's collection.

Alotype: ♀. Length, 12·5 mm.; breadth, 4·75 mm. In author's collection.

Material: Taken also by Mr E. Fairburn, who sent a good series.

Locality.—Stephen Island, Cook Strait.

Remarks.—This species is closely allied to *Leperina sobrina* White (No. 317). In that species the sides of thorax are broadly rounded, and base of elytra sinuated with more broadly rounded shoulders. The almost angulate sides of thorax, and straight, slightly oblique basal margins of elytra of the new species will easily lead to its identification.

CURCULIONIDAE.

Otiorhynchinae.

Inophloeus Pascoe, 1875. *Man. N.Z. Coleopt.,* p. 439.

4337. **Inophloeus quadrinodosus** n. sp.

Oblong, opaque, nigrescent, antennae rufo-piceous, club fuscus, sparsely clothed, with small rounded pinkish scales and straw-coloured decumbent squamae.

Rostrum a little longer than thorax, tricarinate, central ridge extending the full length, lateral hardly reaching point of antennal insertion. Scrobes open above, oblique, not quite reaching eyes. Scape reaching front of eyes, slender, slightly swollen at its junction with funiculus, first joint of funiculus very little longer than second, third to seventh about equal, club elongate, pilose. Eyes oblique, well clear of thorax. Thorax longer than broad, obliquely narrowed towards front and base, front bisinuate with moderately developed ocular lobes, base truncate, there is a rather deep dorsal groove extending from the transverse frontal depression to base, surface rugosely sculptured. Elytra two and a-half times length of thorax, widest on top of declivity where the angles are produced into conical overhanging nodosities from which the elevated fifth interstice forms an incurved ridge which becomes normal before reaching base, there are also two rather large depressions in line with hind thighs and two small ones immediately in front, posterior declivity with a pair of acute conical elevations nearer the top, dorsal area slightly convex, central basal margin a little elevated, shoulders depressed, rounded, sides subparallel, apical portion considerably narrowed, the whole surface with regular rows of elongate, moderately deep punctures. Legs piceous, femora robust, anterior tibia rather long, flexuous, intermediate and posterior nearly straight.

Holotype: ♂. Length (rostrum included) 9 mm.; breadth, 3 mm. In author's collection.

Material: A damaged specimen captured by Mr Sutherland, lighthouse keeper, and put aside in the hope that other specimens would be forthcoming.

Locality.—Puysegur Point, Southland, taken on February 10, 1922.

Remarks.—This species does not appear to have any near allies. *Inophloeus laetificus* Broun (No. 2888) is perhaps the nearest approach to it, but is considerably smaller, with distinct thoracic sculpture.

CYLINDRORHINAE.

Phaeophanus Broun, 1886. *Man. N.Z. Coleopt.* pt. 3, p. 792.

4338. **Phaeophanus fairburni** n. sp.

Robust, large, elongate, convex, dorsal areas with elevations, derm nigrescent, clothed with light coppery and straw-coloured iridescent scales, interspersed with elongate suberect squamae, tibia setose, tarsi with fine, long, hair-like vestiture. Rostrum about as long as thorax, considerably expanded at apex, tricarinate on top and a short one on sides above scrobes, the top outer ones more elevated near front and converging towards base, but becoming obsolete before reaching the eyes, where the centre one also ends in a narrow, elongate depression. Scrobes short, obliquely descending, reaching only a little more than half-way to eyes. Eyes transverse, distant from thorax, the intervening space with oblique, wrinkled sculpture. Scape slender, a little sinuate, just reaching the eyes, funiculus with the first two joints equal, third about two-thirds the length of second, four to seven subequal with elongate setae, club 4-articulate, pilose with a few short, fine setae. Thorax a little longer than broad, about same width at middle and base, narrower in front, sides near base a little compressed, disc uneven with an apical elevation and two small ones behind on each side of the middle, they are connected by an ill-defined obtuse ridge, which also extends behind the elevations, forming an irregular, oval-shaped depression which extends almost to base; there is also a lateral ridge on each side, apex truncate in centre with front angles roundly produced forming ocular lobes, posterior angles broadly rounded, sides subvertical. Elytra oblong, two and a-half times the length of thorax, and about the same width at base, costate, third interstice with three elevations, the basal elongate, also intermediate but lower and interrupted, the other situated on top of the declivity. The whole surface studded with small black granules and large, irregular punctures, those near sides interrupting the costae so as to make them appear serrate, sides gradually rounded from middle to truncate base, and obtuse narrowly rounded apices. Scutellum circular, very small, clothed with light, straw-coloured scales. Underside of head transversely wrinkled. Mesosternal process broad in front, curved backwards in the form of a narrow hook. Metasternum obliquely emarginate between coxae, basal ventral segment longer than second, which is more convex and slightly curved towards front, third very narrow, truncate, fourth about same width as third, posterior margin curved the opposite way to second, fifth wider than third and fourth combined, a little hollowed near the extremity, sixth very small.

Holotype: ♂. Length (rostrum included) 20 mm.; breadth, 7 mm. In author's collection.

Allotype: ♀. Length (rostrum included), 24·5 mm.; breadth, 8·75 mm. Very similar to male, larger and more robust, apical ventral segment not hollowed. In author's collection.

Material: A good series of this fine weevil was also forwarded by Mr E. Fairburn, who spent two nights in seeking its food-plant, which was found to be a species of flax *(Phormium)*, to which it appears to be very destructive. I have much pleasure in naming it in honour of this gentleman.

Locality.—D'Urville Island, Cook Strait, taken at night on the 14th of January, 1931.

Remarks.—This species is a little smaller than the larger specimens of *P. o'connori* Broun (No. 4206), and lacks the pale thoracic stripe. The form and sculpture is also quite different.

NOTE.—Since the above was written, Mr E. Gourlay, of the Cawthron Institute, Nelson, has forwarded to me for inspection a large number of specimens of this weevil, among which is a very rare colour variety. This specimen, which I understand was the first found, and gave a clue to its existence on the island, was picked up dead in the open by Miss Huffam, of Nelson, who was a member of the party which visited the island early in the year. This interesting variety is almost entirely clothed with silvery-grey iridescent scales, with vestiture of the same colour, that of the elevations being lighter with a yellowish tinge. The specimen remains in the collection of Mr Gourlay, who also was a member of the party.

Pparchus Broun, 1904. *Ann. Mag. Nat. Hist.*, ser. 7, vol. 14, p. 114.

4339. **Pparchus gourlayi** n. sp.

Elongate, coppery-brown, costate, clothed with depressed small elongate scales, interspersed with larger recumbent ones. Rostrum tricarinate, the outer converging towards base, and all three ending before reaching front line of eyes, between which there is a punctiform depression, about one-third shorter than thorax, apex broken up with depressions, divided from the swollen sides by a broad, V-shaped channel in which are several setigerous punctures; there is also an elongate fovae on each side above the scrobes, scrobes oblique, reaching front of eyes. Antennae red, scape incrassate, funiculus with first and second joints about equal length, three to seven shorter, all with several fine long setae, club three-articulate, pilose. Eyes transverse, well clear of thorax. Thorax longer than broad, front sinuate, without ocular lobes, base truncate, apex with a longitudinal ridge ending before reaching middle in an elongated depression reaching almost to the basal margin, bordered by interrupted elevations, on each side of the middle in front there is a large, oblique depression with the lower portion ending in an elevated lateral ridge, sides a little compressed behind middle, base rugosely sculptured with black granular elevations, also the raised dorsal area, dorsal and lateral stripes formed by bright straw and cupreous coloured scales. Elytra two and a-half times length of thorax, sides flatly rounded to base and apices, base very little wider than thorax, the third, fifth, and seventh interstices elevated, fifth and seventh terminating at the junction of the fourth, sixth, and eighth, third interrupted on the declivity by second and prolongation of eighth, ninth and tenth a little raised near apices, sutural from the top of declivity, interstitial punctures large, each with a bright scale in centre; the costae are similarly clothed to the thoracic stripes, being lighter on the sides and underneath. Scutellum very small, raised, covered with bright yellow scales. Legs with fine and coarse setae, femora with a narrow band of light-coloured scales. Underside dark, sparingly clothed with coppery scales and recumbent bristles interspersed with numerous black granules. Abdomen elongate, basal segment broadly medially concave, longer than second, third, and fourth combined, about as long as fifth, sixth half the length of third.

Holotype: ♂. Length (rostrum included) 19·5 mm.; breadth, 7 mm. In author's collection.

Allotype: ♀. Length (rostrum included) 23 mm.; breadth, 9 mm. In author's collection. Larger than male, similarly clothed, basal ventral segment very little depressed.

Material: A good series of this very fine species forwarded by Mr E. Fairburn. It was first discovered by Mr E. S. Gourlay, first assistant entomologist of the Cawthron Institute, Nelson, after whom I have much pleasure in naming it.

Locality.—Balloon Hut, Mount Arthur, Nelson. Taken at a height of 4300ft., on January 8, 1930.

CRYPTORHYNCHINAE.

Aldonus White, 1846. *Voy. Ereb. and Terr.*, Ins., p. 16.

4340. **Aldonus insularis** n. sp.

Elongate, convex, very dark brown thickly clothed with drab scales and squamae of same colour, interspersed with dark brown, the latter forming irregular markings on elytra.

Antennae and legs piceo-rufus, funiculus setose, scape incrassate, punctate, club pilose. Rostrum piceous, with three fine carina, central one straight, outer somewhat sinuated, moderately stout, a little constricted about middle and considerably more so between eyes, apical portion sculptured with irregular longitudinal lines. Scrobes almost straight, reaching front of eyes. Head small, eyes truncate in front, not prominent, well clear of thorax. Thorax about one-fifth broader than long, as wide as elytra at middle, narrowed to width of head in front, base bisinuate, not quite so wide as that of elytra, apex truncate, front angles descending to almost beneath, roundly produced, widest behind middle, a little depressed on each side of the middle in front, the whole surface rather coarsely sculptured. Elytra a little more than twice the length of thorax, sides almost parallel to hind thighs, then gradually narrowed to apices, which are individualy rounded, striae interrupted with large punctures, interstices with numerous black granular elevations, which together with the punctures gives the whole surface a very rough appearance; there are also a number of irregular, semi-zigzag dark markings distributed over the surface, shoulders a little prominent. Scutellum minute, depressed, punctate. Legs clothed with elongate drab scales and coarse bristles, more densely so on tibia and tarsi, femora deeply notched near extremity with a short, stout spine on its upper edge. Underside shining, with large and small punctures, interspersed with long yellowish scales. Rostral canal moderately deep, not limited by margins of coxal cavities, but extending to mesosternal process, which is more deeply emarginate and has the borders more elevated than any other member of the genus. These characters combined with its dark colour and peculiar markings will enable it to be easily identified.

Holotype: ♂. Length (rostrum included), 11·5 mm.; breadth, 4·5 mm. In author's collection.

Allotype: ♀. Length (rostrum included), 10·5 mm.; breadth, 4 mm. In author's collection. Rather more slender than the male, colour and sculpture similar, shoulders more prominent, antennae inserted a little before middle of rostrum, which is shining, punctate, and more slender than that of male, wider between eyes, and not constricted there.

Material: A good series also from Mr E. Fairburn.

Locality.—Stephen Island, Cook Strait, taken on January 12, 1931.

A variety of this species was taken on D'Urville Island, also by Mr Fairburn. Rather smaller than typical specimens, the male has the rostrum more slender and not so abruptly constricted between the eyes, colouration and sculpture similar.

♂. Length (rostrum included), 10 mm.; breadth, 3·75 mm.

♀. Length (rostrum included), 10·5 mm.; breadth, 3·5 mm.

Several specimens taken on January 14, 1931, are in the writer's collection.

Report upon a Collection of Chermidae (Homoptera) from New Zealand.

By G. F. FERRIS and F. D. KLYVER, Stanford University, California.

[*Communicated by Dr David Miller.*]

FOR the material upon which the present report is based we are indebted to Dr J. G. Myers, now of the Imperial Bureau of Entomology, but formerly of New Zealand. It is an extremely important collection, for it represents the first extensive gathering of material in this family in New Zealand. There were included in it perhaps four hundred and fifty pinned specimens, a few of which represented nymphal stages. Unfortunately, however, for most of the material host data are lacking, and in some cases but one sex is represented or the material is otherwise limited. But with this collection available it has been possible to make a definite beginning in the study of the New Zealand fauna of this family.

The holotypes and allotypes of all the new species described, together with most of the other material, are returned to Dr Myers. Paratypes and representatives of other species are retained in the Stanford University collection.

We recognise in the collection a total of twenty-five species, these including three which have previously been described from New Zealand. Of the twenty-two remaining species we have been able to connect none with named forms from other parts of the world, and all are described as new. Possibly some of these will later fall as synonyms, but this we are inclined to doubt. There is no reason to suppose that any of them are introduced forms, and the isolation of New Zealand argues against the probability that these species occur elsewhere.

Six species of Chermidae have heretofore been recorded from New Zealand. Of these we have been unable to recognise two as present in the material at hand, although they will doubtless be definitely determinable if taken from their typical hosts and localities. Of the other four we consider one to be a synonym. Thus there are at present twenty-seven species known from these islands. This is in all probability but a comparatively small proportion of the species that are actually present. This being the case, an analysis of the fauna can have but little significance, but it may be of interest to give at least a short summary. The results, as they stand at present, are rather striking.

We recognise in this material three subfamilies—following the arrangement by Crawford—the Psylliinae, Triozinae, and Pauropsyllinae. Of these the Psylliinae is represented by two genera, the Triozinae by one and the Pauropsyllinae by two. The Triozinae, with the one genus *Powellia,* is extraordinarily well represented, for of the twenty-seven species from the islands, fifteen may be referred to it.

Of the two genera of the Psylliinae, *Psyllia* has five and *Ctenarytaina* four species, and each of the genera of the other two subfamilies but one.

It has been our desire to adopt a conservative point of view in the matter of genera, but after considerable hesitation we have restored the long-forgotten genus *Powellia* and have named as new the genus *Ctenarytaina*. These two genera at present stand as peculiar to New Zealand, but probably other species from at least the paleotropics are to be added to both.

A word concerning our method of study is desirable. We hold to the view that satisfactory systematic work, especially upon forms as small as these, cannot be accomplished on the basis of the conventional pinned material alone. It is impossible in such specimens even to see, still less appreciate and understand, many of the structures which must be utilised if we are to know our material and our species in any precise and definite way. Consequently we have followed the methods which have been developed especially by students of the Coccidae, and have mounted upon slides all our material from which we desired to obtain information other than notes on colour and habitus. The types of all the new species described have been chosen from such material, and our figures and descriptions of structure based upon it.

That there are difficulties in applying this method to such forms must be recognised. These insects are rather difficult to prepare properly, for they are fragile and subject to much distortion and other damage during the course of preparation. Certain characteristics which have been much used by other authors, such as the exact profile of the thorax and the angle of the head, are difficult to preserve or are lost entirely. Consequently it is desirable to retain some material upon pins or to make careful notes before the specimens are prepared. In all cases, however, where material has been limited, we have chosen deliberately to place it upon slides rather than keep it on pins.

List of Species Previously Recorded from New Zealand, with Their Present Disposition.

Powellia vitreoradiata Maskell.

Here recognised and restored as the type of the genus *Powellia*.

Trioza pellucida Maskell.

Here recognised and placed as a synonym of *Powellia vitreoradiata* Maskell.

Trioza alexina Marriner.

Here recognised and placed as a synonym of *Powellia vitreoradiata* Maskell.

Trioza panacis Maskell.

Not here recognised, but placed as a probable member of the genus *Powellia*.

Psylla acaciae Maskell.

Here recognised as a species of *Psyllia*[1].

Rhinocola fuchsiae Maskell.

Here recognised and assigned to the genus *Ctenarytaina.*

Rhinocola eucalypti Maskell.

Not here recognised. It may possibly be one of the species here referred to *Ctenarytaina.*

Key to Genera dealt with in this report: This key is based exclusively upon the material included in this report, and consequently makes no allowance either for other genera which may later prove to be represented in New Zealand or for generic limits wider than here indicated[2].

1. Fore wings with the veins dichotomously branched, radius, media, and cubitus thus not arising from a common point....2

   Fore wings with radius, media, and cubitus arising from a common point:

   Genus **Powellia** Maskell.

2. Posterior tarsi with at least one, and generally two, black, claw-like spines at apex of basal segment.................3

   Posterior tarsi without such claw-like spines:

   Genus **Pauropsylla** Rübsamen.

3. Head with definite genal processes or cones.................4

   Head without genal cones:

   Genus **Metaphalara** Crawford.

4. Middle tibia with a distinct, although minute, longitudinal comb of setae near the apex:

   Genus **Ctenarytaina,** new genus.

   Middle tibiae without such a comb of setae:

   Genus **Psyllia** Kirkaldy.

Subfamily TRIOZINAE, Puton.

Genus Powellia, Maskell.

1879. *Powellia,* Maskell. *Trans. N.Z. Inst.,* 11:223.

1890. *Trioza,* Maskell, *Ibid.* 22:104.

The genus *Powellia* was originally established by Maskell for the reception of the species *vitreoradiata* Maskell. This species was based upon the nymph of a Chermid, which Maskell erroneously supposed to be a Coccid. Later, upon discovering his error, he redescribed the species from adults and assigned it to *Trioza,* at the same time rejecting his earlier specific name and substituting for it the specific name *pellucida.*

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[1] The spelling *Psyllia,* instead of *Psylla,* is here employed in accord with the views of hemipterists.

[2] For extensive keys see Crawford, Philippine Journal of Science, 15: 139-205. 1915.

Under the at present generally accepted International Code of Nomenclature, the specific name *vitreoradiata* must stand and the generic name *Powellia,* even though based upon a misconception, is available. The only question is whether it is desirable to recogise the genus as distinct from other triozine genera. The writers of this paper are opposed in principle to the undue multiplication of genera, but after a careful study of *Trioza urticae* (Linnaeus), the type of the latter genus, and of representatives of related triozine genera, we have come to the conclusion that there are valid reasons for the recognition of the genus *Powellia.* We present the following statement of its characters.

Triozine Chermidae in which the radius, media, and cubitus of the fore wing diverge from a common point; posterior border of the wing with three areas of black, sclerotic points (alar radulae); genae conical and more or less divergent, declivous and not in the same plane with the distinctly bulging vertex; thorax quite strongly arched; posterior coxae without a forward directed spur in addition to the normal posterior spur; posterior tibiae with a clearly evident spur or series of spurs at the base and armed with a subapical, almost thumb-like spur on the outer, posterior margin and with three apical spurs on the inner margin; antennae not hairy; wings variable in form and pigmentation; genitalia variable.

Type of the genus, *Powellia vitreoradiata* Maskell (= *Trioza pellucida* Maskell = *Trioza alexina* Marriner).

From the genus *Trioza, Powellia* is separable by the characters of the posterior tibiae, *Trioza urticae* lacking entirely the basal spurs and, although having the same number of apical spurs lacking the characteristic arrangement found in *Powellia.* From *Phyllopecta* (= *Megatrioza*), although having the same tibial characters, it differs in lacking the anterior spur of the posterior coxae, which is the distinctive feature of the latter genus. The fifteen New Zealand species here recognised differ greatly among themselves in regard to the details of the wings and the genitalia, but while it is possible to recognise groups of species, such as that centring about *vitreoradiata,* we do not believe that any further dividing is desirable at the present time.

KEY TO THE SPECIES OF POWELLIA.

Females.

1. Fore wings definitely pigmented throughout..................2
   Fore wings hyaline, or with at the most a barely visible general pigmentation or with bands or spots..................4
2. Genitalia with the dorsal plate long, slender, and distinctly decurved:
   Powellia decurvata, sp. n.
   Genitalia with the dorsal plate not decurved...............3

3. Radial sector ending close to the apex of the wing, cell R_1 slender and somewhat curved:
Powellia obfusca, sp. n.

Radial sector ending remote from the apex of the wing, cell R_1 broad and wedge-shaped:
Powellia colorata, sp. n.

4. Genitalia with the valves blunt, the apex of neither plate produced into a point....................................5

Genitalia with at least the dorsal plate produced into a point..7

5. Fore wings with the membrane beset in the distal half with punctations except along the veins:
Powellia equalis, sp. n.

Fore wings with punctations at the most only at the base....6

6. Fore wings entirely without punctations, completely hyaline:
Powellia curta, sp. n.

Fore wings with punctations toward the base and with pigmented bands:
Powellia fasciata, sp. n.

7. Both dorsal and ventral plates of the genitalia strongly constricted and with at least the apical third slender, acute, and more or less up-turned..........................8

Dorsal and ventral plates tapering, or if the dorsal valve is constricted it is decurved..............................10

8. Apical parts of the ovipositor elongate and slender, palps transversely striate:
Powellia styligera, sp. n.

Apical parts of ovipositor of ordinary form, palps radially striate 9

9. Fore wings punctate throughout except along veins:
Powellia subacuta, sp. n.

Fore wings with punctations at the most only at base:
Powellia acuta, sp. n.

10. Dorsal plate of genitalia decurved at apex:
Powellia irregularis, sp. n.

Dorsal plate of genitalia not decurved at apex............11

11. Fore wings beset throughout, except along veins, with conspicuous punctations:
Powellia, bifida, sp. n.

Fore wings at the most with punctations only at base........12

12. Posterior border of fore wings with a narrow, pigmented band:
Powellia falcata, sp. n.
Posterior border of fore wings without pigmented band......13

13. Costal cell of fore wings typically with a large, pigmented spot; dorsal plate of genitalia scarcely exceeding ventral:
Powellia emarginata, sp. n.
Costal cell of fore wings without pigmented spot; dorsal plate of genitalia distinctly exceeding ventral:
Powellia vitreoradiata.

Males.

NOTE.—The males of several species are unknown.

1. Claspers expanded and emarginate or bifid at the apex........2
Claspers not expanded and emarginate or bifid at apex......5

2. Claspers slender deeply bifid at apex, without sclerotic spur or fold at apex on inner side:
Powellia bifida, sp. n.
Claspers broad and shallowly emarginate at apex, with a sclerotic fold or spur at apex on inner face..................3

3. Claspers with merely a sclerotic fold, not a spur on inner face at apex:
Powellia emarginata, sp. n.
Claspers with a spur on inner face at apex.................4

4. Fore wings hyaline:
Powellia vitreoradiata (Maskell).
Fore wings with a narrow, pigmented band on posterior border:
Powellia falcata, sp. n.

5. Claspers pyriform, acute at the apex and curved posteriorly:
Powellia curta, sp. n.
Claspers not so...6

6. Claspers diagonally truncate at apex:
Powellia acuta, sp. n.
Claspers not diagonally truncate at apex..................7

7. Fore wings pigmented throughout, punctations small and everywhere present:
Powellia decurvata, sp. n.
Fore wings hyaline, punctations conspicuous but lacking in areas paralleling the veins:
Powellia subacuta, sp. n.

Powellia vitreoradiata Maskell. (Pl. 7, Figs. A-N; Pl. 8, Figs. A-D; Pl. 16, Figs. E-G.)

1879 *Powellia vitreoradiata* Maskell. *Trans. N.Z. Inst.*, 11, 223-225; Pl. 8, Fig. 22.

1890. *Trioza pellucida* Maskell, *Ibid.* 22, 164-167; Pl. 11.

1903. *Trioza alexina* Marriner, *Ibid.* 35, 305-309; Pls. 34, 35.

Previous Records.—Recorded by Maskell from *Pittosporum eugenioides, Discaria toumatou* and *Geniostoma ligustrifolium*, "throughout New Zealand," and by Marriner from *Pittosporum tenuifolium*, without indication of locality. We accept specimens on *Pittosporum* as being typical.

Specimens Examined.—"From leaf pits on *Pittosporum crassifolium*," Wellington; Wellington and Waitakerei Hills, Auckland, without host indication (all J. G. Myers). Numerous specimens, including nymphs from Wellington.

NOTES.—We are quite well satisfied as to the identity of this species and as to the synonymy indicated. The figure of the male genitalia given by Maskell is, we are convinced, quite erroneous, the three remarkable hooks at the apex of the clasper being a misinterpretation of the actual condition, the same illusion being evident in some of our material. If this interpretation be accepted—and the host data are additional evidence in its favour—it is clear that *Trioza alexina* Marriner is a synonym. The erroneous change of name by Maskell is discussed above.

This species being the type of its genus we shall discuss it here in detail, and shall describe the other species of the genus chiefly by reference to it.

MORPHOLOGY OF THE SPECIES.

Head (Pl. 7, Fig. I) with the genal cones slightly shorter than the length of the vertex, quite sharply conical and rather strongly divergent, considerably depressed beneath the plane of the vertex, which is thus rather strongly bulging. Median furrow of the vertex strongly defined. Frons represented only by the anterior ocellus and probably by a triangular piece which appears on the posterior aspect of the head. Setae of the head few, inconspicuous, longer on the genae. Antennae (Pl. 7, Fig. M) about one and a-half times as long as the width of the head, presenting no special characteristics.

Thorax (Pl. 7, Fig. A) rather strongly arched, the pronotum declivous, the derm beset with minute ridges (Pl. 7, Fig. B) and little or not at all hairy. Posterior tibiae with several strong spurs at the base (Pl. 7, Fig. D) and with the characteristic arrangement of the black spurs at the apex (Pl. 7, Fig. F), there being a posterior, sub-apical and rather thumb-like spur and an apical comb of small setae on the outer aspect and three strong spurs on the inner aspect. Posterior femora with a small cluster of blunt setae near the apex on the anterior aspect. Posterior tarsi (Pl. 7, Fig. L) presenting no unusual characters.

Fore wings (Pl. 8, Fig. A) entirely hyaline, three times as long as wide, quite acute at the apex, the membrane entirely free of punctations except for a few near the base; with the usual three clusters of black, sclerotic points (Pl. 8, Fig. C), to which we are here applying the term " alar radulae." Radial sector curved, reaching nearly to the apex of the wing. Marginal cells subequal in size. Veins beset with minute setae. Posterior wings with the membrane thickly beset with minute, black punctations and with the veins defined entirely by larger sclerotic points (Pl. 8, Fig. D) and not at all by pigmentation of the wing membrane.

Abdomen (Pl. 7, Fig. A) with the tergites and sternites but moderately sclerotic. Genital segments of the female (Pl. 7, Fig. K) comprising slightly more than half the total length of the expanded abdomen, tapering regularly to a quite acute apex, with the dorsal plate slightly longer than the ventral and bearing an apical area (Pl. 7, Fig. N) of small, stout, retrorse, setae; gape of the genital segments but slight. Apodemes of the ovipositor slightly exceeding the genital segment in length, the apex of the " main rod " of the usual halberd shape, the tips of the lateral rods not serrate, the " palps " small and radially striate. Circumanal pore ring (Pl. 7, Fig. H) composed of a double row of pores, those of the outer row small and circular, those of the inner row elongate.

Genitalia of the male (Pl. 7, Fig. G) with the proctiger (anal valve) expanded into a roundly convex lateral wing on each side, this bearing a few slender setae near the apex. Claspers of a distinctive form, the anterior margin (Pl. 7, Fig. J) with a deep notch, the tip expanded and bilobed, the inner aspect bearing a strong subapical ridge which forms a basally directed, blunt, sclerotic point.

COLOUR AND HABIT NOTES.

Colour evidently variable, ranging from a general light bluish green with brownish markings on head and thorax to a general pale yellowish brown; eyes brown, ocelli bright red.

NYMPH.

Occurring in pits on the leaves of the host; flat and with a secretionary fringe of delicate threads around the margin and probably also with such threads arising from the dorsum.

A typical triozine nymph, that is with the anterior wing pads produced forward and partially enveloping the head, with the dorsum entirely sclerotic except for the cervical and thoracic-abdominal articulations, and beset especially on the margin with the characteristic modified setae to which the term " sectasetae " has elsewhere been applied.

Length on slide 2 mm. General body form (Pl. 16, Fig. E) rather broadly oval. Sectasetae (Pl. 16, Fig. F) of various sizes, set in an irregular marginal series and sparsely distributed over the dorsum. Antennae short, six-segmented. Anal pore ring on the ventral side of the body, enclosing a narrow, transverse area and composed of a single row of narrow, elongate pores enclosing an indefinite row of small, circular pores. Empodium (Pl. 16, Fig. G) sessile, fan-shaped.

Powellia falcata, sp. n. (Pl. 8, Fig. F; Pl. 9, Fig. B.)

Specimens Examined.—Holotype, a male, and paratype males and nymphs from *Aristotelia serrata*, Pokako (D. Miller) and males without indication of host from Leith, Dunedin (G. Howes).

Colour.—No notes available.

Structure.—In the male differing from *P. vitreoradiata,* to which it appears to be very closely related, only in the following characters. Fore wing (Pl. 9, Fig. F) rounded at the apex and typically with a longitudinal, narrow band of brownish colour along the basal half of the posterior margin, although some specimens seem to lack this; wing membrane without punctations except a few at the base. Genitalia (Pl. 9, Fig. B) differing from those of *vitreoradiata* in having the sclerotic, apical process on the inner face of the claspers in the form of a distinct, foward pointing hook and in having the notch on the anterior margin of the claspers much broader.

Nymph.—Occurring in pits on the leaves of the host. Differing from the nymph of *P. vitreoradiata* primarily in having the sectasetae confined to a single regular marginal row and an ill-defined submarginal series, there being none on the remainder of the dorsum and all being of a single size.

Powellia emarginata, sp. n. (Pl. 9, Figs. D, F; Pl. 8, Fig. H.)

Specimens Examined.—Holotype, a male, and allotype and two paratypes, Arthur's Pass, 3000 feet (J. G. Myers); one female from "kiekie" (*Freycinetia Banksii*), York Bay (J. G. Myers).

Colour.—Head, thorax, and genitalia ranging in general colour from a comparatively dark, reddish brown with the abdomen red, to a lighter brown with greenish markings on head and thorax and the abdomen green. Wings slightly brownish, with a very distinct, dark spot in the costal cell.

Structure.—In general resembling *P. vitreoradiata* quite closely. Antennae slightly more than twice as long as width of head. Fore wings (Pl. 8, Fig. H), as in *P. vitreoradiata,* without punctations but slightly broader and less acute at the apex and with the radial sector shorter and forming a wedge-shaped cell. Genitalia of female (Pl. 9, Fig. F) relatively shorter than in *vitreoradiata,* with the dorsal plate scarcely exceeding the ventral in length and bearing but a very few retrorse setae at the apex. Genitalia of the male (Pl. 9, Fig. D) of the same type as in *vitreoradiata* but with the claspers much broader and with merely a somewhat sclerotic fold on the inner face at the apex.

Powellia bifida, sp. n. (Pl. 8, Fig. J; Pl. 9, Fig. I; Pl. 10, Fig. E.)

Specimens Examined.—Two specimens only, the holotype, a male, from Arthur's Pass, 3000 feet (J. G. Myers), and the allotype from Leith, Dunedin (G. Howes).

Colour.—No notes available.

Structure.—Quite similar to *P. vitreoradiata.* Differing in the character of the fore wings (Pl. 8, Fig. J), which are rounded at the tip and have the wing-membrane beset throughout with quite evident punctations except for narrow spaces paralleling the veins. Hind wings with the venation formed in the same manner as in *vitreoradiata,* but with the rows of large points tending to be double. Genitalia of the female (Pl. 10, Fig. E) relatively long, forming approximately two-thirds of the expanded abdomen, acute at the apex, with the dorsal plate considerably exceeding the ventral and thickly beset in its apical third with small, retrorse setae. Genitalia of the male (Pl. 9, Fig. I) differing from those of *vitreoradiata* in having the proctiger long, quite slender and tapering, and with a row of quite long setae along the posterior margins, and in having the claspers also long and quite slender and deeply bifid at the apex with the posterior lobe heavily sclerotic, and without a fold or hook on the inner face at the apex.

Notes.—Our association of this male and female is solely on the basis of the wing characters, the shape and the arrangement of the punctations being so closely similar in the two that it seems reasonable to put them together.

Powellia acuta, sp. n. (Pl. 10, Figs. A, C.)

Specimens Examined.—Holotype, a female, and allotype and twenty-eight paratype males and females from *Cassinia leptophylla,* Ohiro, Wellington; one female from *Cassinia leptophylla,* Orongorongo, Wellington.

Colour.—Of a general pale green colour, with brownish markings on head, thorax, and genitalia, varying to a general brown with the abdomen greenish; wings very pale brown, not quite hyaline.

Structure.—Genae slightly shorter, blunter, and less divergent than in *P. vitreoradiata.* Antennae about twice as long as width of head. Fore wings (Pl. 9, Fig. H) but little more than twice as long as wide, rounded at the apex, radial sector attaining practically the tip of the wing; membrane without punctations except in claval area. Hind wings with the venation formed by the concentration of the small dots into three or four rows, but without pigmentation of the membrane. Genitalia of the female (Pl. 10, Fig. A) forming slightly more than half the length of the expanded abdomen, of a distinctive type, the dorsal plate with its apex forming a long, slender, and rather sclerotic process which is beset with small, retrorse setae. Ventral plate likewise acute, slightly shorter than the dorsal. Dorsal plate with a tuft of quite long setae just before the base of the apical process. Genitalia of male (Pl. 10, Fig. C) with the proctiger stout, its posterior margin strongly convex and fringed with hairs, the claspers rather short and broad, diagonally truncate at the apex and with a narrow, sclerotic apical rim.

Powellia subacuta, sp. n. (Pl. 10, Figs. D, F.)

Material Examined.—Holotype, a female, and allotype, Wilton's Bush; two paratype females, Wellington Botanical Gardens (J. G. Myers); one paratype female, Day's Bay, Wellington; one paratype female, York Bay, Wellington (I. H. Myers).

Colour.—Notes not available.

Structure.—Very close to *P. acuta.* Wings, however, beset throughout with punctations except for narrow areas paralleling the veins. Genitalia of female (Pl. 10, Fig. D) with the prolongation of both dorsal and ventral plates shorter and less acute. Genitalia of the male (Pl. 10, Fig. F) with the proctiger strongly angular and the claspers slender, tapering slightly in their apical fourth to the truncate apex.

Powellia decurvata, sp. n. (Pl. 10, Figs. H, I.)

Specimens Examined.—Holotype, a male, and a paratype male, York Bay, Wellington (J. G. Myers); allotype, Mount Maunganui, Wellington, 2300 feet (J. G. Myers); males and females, Bull Mound, Tararua Mts., 3300 feet; female, Arthur's Pass (J. G. Myers); male, Auckland (J. G. Myers).

Colour.—Of a general light brown colour with darker markings on head and thorax; wings very pale brown.

Structure.—Antennae about one and a-half times as long as the width of the head. Genae fully as long as the vertex and noticeably slender. Wings slightly rounded at apex, the radial sector almost attaining apex and paralleling costal margin, membrane punctate throughout, more strongly so at base, without bare areas along veins. Hind wings with veins formed by a slight pigmentation of the membrane and a concentration of the small points. Hind tibiae with the basal spurs rather weakly developed. Genitalia of female (Pl. 10, Fig. H) forming two-thirds of the length of the expanded abdomen, the dorsal plate considerably exceeding the ventral, tapering regularly to the apex and strongly curved downward, the two plates gaping widely. Genitalia of male (Pl. 10, Fig. I) with the proctiger elongate and somewhat flask shaped, the posterior border beset with a fringe of long setae; claspers quite long, moderately slender, parallel-sided, with the apex rounded and without hooks or sclerotic processes, the inner face with numerous small setae near apex.

Powellia fasciata, sp. n. (Pl. 8, Fig. I; Pl. 9, Fig. A; Pl. 11, Fig. A.)

Specimens Examined.—But two specimens, both females, holotype from Ohakune (J. G. Myers), the other from Longacre, Wanganui (J. G. Myers).

Colour.—Notes not available. Wings in the type with a conspicuous brown border along the posterior margin of the wing, which is continued across the base of the wing as a rather narrow transverse band. In the paratype (Pl. 9, Fig. A) the pattern is different, there being two transverse bands across the basal half of the wing, with the band along the posterior border lacking.

Structure.—A very robust species, with the derm heavily pigmented. Antennae twice as long as the width of the head. Genal cones (Pl. 8, Fig. I) scarcely more than half as long as the vertex, parallel, broad, and bluntly rounded at the apex. Derm without imbrications. Dorsum of thorax distinctly hairy. Wings slightly less than three times as long as wide and but moderately acute. Radial sector short, ending remote from the apex and forming a cuneate cell. First marginal cell much smaller than the second. Membrane of wing punctate only at the base. Hind wings with the veins formed by large sclerotic points; base and anterior margin of wing brownish. Genitalia of female (Pl. 11, Fig. A), the dorsal plate quite broadly truncate at the tip and greatly exceeding the small ventral plate; ovipositor with the terminal parts very small and obscure.

Notes.—The two specimens at hand differ noticeably in the pigmentation of the wing, that here figured being the paratype. However, they agree so closely in structural characters that on the basis of the material at hand they appear to be the same species.

Powellia curta, sp. n. (Pl. 8, Fig. K; Pl. 10, Fig. G.)

Specimens Examined.—Holotype, a female, and two paratype females from *Metrosideros tomentosa,* Kaitaia (J. G. Myers); allotype male from " kiekie " (*Freycinetia Banksii*), York Bay (J. G. Myers).

Colour.—Dark brown throughout, the wings hyaline.

Structure.—Antennae about two and a-half times as long as width of head, noticeably slender. Genae (Pl. 8, Fig. K) scarcely more than half the length of the vertex, stout, but rather acute at the apex. Dorsum of the thorax with conspicuous hairs. Posterior tibiae with a single well-developed spur at base. Wings about three times as long as wide, somewhat more acute at the apex even than in *vitreoradiata,* radial sector terminating remote from apex and forming a wedge-shaped cell. Genitalia of female very short (Pl. 10, Fig. G), scarcely longer than the preceding segment, the dorsal plate but little surpassing the ventral, the ovipositor very small. Genitalia of male (Pl. 10, Fig. B) likewise very small, the proctiger almost globular, the claspers pyriform, tapering to an acute apex which is curved posteriorly and is heavily sclerotic, the inner face of the claspers with a transverse row of small setae.

Notes.—In the character of the genitalia of the female of this species seems to be closest to *P. fasciata.*

Powellia styligera, sp. n. (Pl. 10, Fig. C.)

Specimens Examined.—A single female from Mt. Alpha, 4000 feet, Tararua Mts.

Colour.—No notes available.

Structure.—Antennae scarcely twice as long as width of head. Genae sharply conical, acute at the apex, scarcely as long as the vertex. Hind tibiae with two or three weakly developed basal spurs. Wings hyaline, beset with fine punctations except for areas paralleling the veins, about two and a-half times as long as broad, quite similar in form to the wing of *P. bifida* (Pl. 9, Fig. H). Genitalia forming about half the total length of the expanded abdomen, the caudal half almost awl-like in form (Pl. 11, Fig. C), with the ovipositor strongly developed and its terminal parts much elongate, the " palps " strongly transversely striate; dorsal plate but little exceeding the ventral, the latter slightly serrate in the apical third.

Powellia obfusca, sp. n. (Pl. 9, Fig. G; Pl. 11, Fig. F.)

Specimens Examined.—A single female from *Hebe salicifolia,* Silverstream, Wellington.

Colour.—Notes not available. Wings quite brown, faintly and irregularly mottled, highly punctate, the punctations irregular in size; alar radulae inconspicuous.

Structure.—Antennae scarcely twice as long as width of head. Genae sharply conical, acute at apex, slightly shorter than vertex. Posterior tibiae with several weakly developed spurs at base. Fore wings (Pl. 9, Fig. C) of a form most unusual in this group, the anterior margin almost straight, the apex well forward of the centre of the wing; radial sector reaching practically to the apex almost straight and forming a long wedge-shaped cell; first marginal cell distinctly longer than second; veins noticeably thick; alar radulae with the points much reduced in size, forming mere roughnesses. Hind wings with the exceedingly faint veins formed by a combination of pigmentation of the mebrane with a concentration of minute points. Abdomen weakly sclerotic. Genitalia of female (Pl. 11, Fig. F) forming about half the total length of the expanded abdomen, tapering regularly to a rather acute apex, the dorsal plate beset with small, retrorse setae at apex; the gape wide.

Notes.—The peculiar wings constitute the most distinctive feature of this species.

Powellia irregularis, sp. n. (Pl. 11, Fig. E.)

Specimens Examined.—Holotype, a female, and one paratype female from Mt. Alpha, 3600 feet; a paratype female from Arthur's Pass (J. G. Myers).

Colour.—No notes available. Wings hyaline.

Structure.—In general characters very close to *P. vitreoradiata.* Antennae about one and a-half times as long as width of head. Hind tibiae with two large and several small spurs at base. Fore wings with the membrane everywhere beset with quite large punctations except for bare areas paralleling the veins; form practically as in *vitreoradiata.* Hind wing with veins formed from unusually large points. Genitalia of female (Pl. 11, Fig. E) forming somewhat less than half the total length of the expanded abdomen, noticeably irregular in form, the valves about equal in length, widely gaping, the dorsal valve quite acute at the apex and somewhat down-curved.

Note.—The irregular form of the ovipositor is the most distinctive feature of this species.

Powellia equalis, sp. n. (Pl. 11, Fig. D.)

Specimens Examined.—One female, Arthur's Pass (J. G. Myers).

Colour.—No notes available. Fore wings hyaline, except posterior margin brown.

Structure.—Antennae about one and a-half times as long as width of head. Genae about two-thirds the length of the vertex, conical, quite blunt at the apex. Hind tibiae with two large and several small spurs at base. Wing form about as in *P. falcata* (Pl. 8, Fig. F), membrane punctate in apical half and along posterior margin to base, with bare areas along the veins. Genitalia (Pl. 11, Fig. D) with the dorsal and ventral plates equal in length and the ventral plate somewhat larger than the dorsal, the plates almost equal in form, rounding to a very blunt apex and with a slight gape.

Notes.—The curiously symmetrical genitalia are distinctive.

Powellia colorata, sp. n. (Pl. 8, Fig. G; Pl. 9, Fig. E; Pl. 11, Fig B.)

Specimens Examined.—A single female from Arthur's Pass.

Colour.—No notes available. Fore wings (Pl. 9, Fig. E) dark brown throughout, somewhat paler toward the base, with an almost hyaline spot followed by a very dark area just beyond the tip of the clavus.

Structure.—Antennae somewhat more than twice as long as width of head. Genae distinctly shorter than vertex, broadly divergent, rather blunt at apex. Hind tibiae with two or three strong and several weaker spurs at base. Wings only slightly more than twice as long as broad, broadly rounded at apex; radial sector short, forming a wedge-shaped cell; marginal cells large and nearly equal; alar radulae with the points small and tending to be arranged in pairs; wing membrane generally beset with large sparse punctations which are lacking along the veins. Posterior wings with the veins defined by pigmentation and not by dots. Genitalia of female forming about one-third of the total length of the expanded abdomen (Pl. 11, Fig. B), the dorsal plate constricted in its apical third and forming an obtuse process, slightly exceeding the ventral plate, the gape wide; ovipositor with terminal structures very small.

Notes.—The striking wings are the most distinctive feature of this species.

Powellia panacis (Maskell).

1890. *Trioza panacis* Maskell. *Trans. N.Z. Inst.*, 22, 167; Pl. 12, Fig. 1-12.

Previous Records.—Recorded by Maskell as " in New Zealand " on *Panax* sp. and *Pseudopanax ferox.*

Notes.—We have been unable to recognise this species in the material at hand, and we can hazard no opinion concerning it other than that it apparently belongs to this group.

Genus PSYLLIA Kirkaldy.

To this genus (which is the genus *Psylla* of most authors) we are referring five New Zealand species. All of these differ from typical members of the genus in the short genal cones. In fact one species departs so widely in this respect that upon the ordinarily accepted bases of classification it might not even be referred to this group, the genae being merely low, rounded and widely separated prominences such as occur in the Liviinae. However, the sum total of its characters indicates unmistakably that it belongs with the other New Zealand species. They may very well remain in the genus *Psyllia* until and unless a survey of the entire genus as now understood reveals more adequate reasons for subdivision.

We would here call attention to a peculiar condition occurring in certain of the species at hand. Normally in the Psylliinae there are present on the basal segment of the posterior tarsi a pair of stout claw-like spurs, the character being one of the characteristics of this group, although it is shared with some others. In certain of the species to be discussed there is but a single claw present, this being the condition which prevails in some of the species of the Pauropsyllinae. That the difference here has no special significance is indicated by the fact the species are obviously closely related upon the basis of other characters.

KEY TO THE NEW ZEALAND SPECIES OF PSYLLIA.

Females.

1. Dorsal valve of the genitalia strongly declivous, scarcely exceeding the ventral valve..............................2

   Dorsal valve of the genitalia not strongly declivous............3

2. Fore wing with conspicuous Y-shaped maculations at margin:

   Psyllia acaciae (Maskell).

   Fore wing without such markings:

   Psyllia uncatoides, sp. n.

3. Dorsal valve of the genitalia with the apical third slender and more or less acute, slightly upturned....................4

   Dorsal valve of genitalia decurved, not slender and acute:

   Psyllia uncata, sp. n.

4. Fore wing with maculations only in the apical third and anterior to the clavus:

   Psyllia albizziae, sp. n.

   Fore wing entirely maculate, sometimes with the apical fourth conspicuously dark:

   Psyllia apicalis, sp. n.

Males.

1. Proctiger without expanded lateral lobes:

   Psyllia apicalis, sp. n.

   Proctiger with strongly expanded lateral lobes...............2

2. Lateral lobes of the proctiger without a hook-like secondary lobe on the posterior margin:

   Psyllia acaciae (Maskell).

   Lateral lobes of the proctiger with a hook-like secondary lobe on the posterior margin...................................3

3. Claspers elongate, parallel-sided, the extreme apex curved posteriorly and forming a sclerotic point:

   Psyllia uncata, sp. n.

   Claspers otherwise formed, pyriform or aciculate.............4

4. Claspers slender, aciculate:

   Psyllia albizziae, sp. n.

   Claspers pyriform, with a pronounced basal lobe on anterior margin:

   Psyllia uncatoides, sp. n.

Psylliae acaciae (Maskell). (Pl. 12, Figs. A, B, C, G, H; Pl. 13, Figs. A, H, I; Pl. 16, Figs. H, I, J, L.)

1894. *Psylla acaciae*, Maskell, *Entomologist's Monthly Magazine*; 30, 171.

Previous Records.—Recorded by Maskell from *Acacia melanoxylon* at Wellington, N.Z.

Specimens Examined.—Nymphs and many adults from Wellington and one female from Rangitoto, all without indication of host (J. G. Myers).

Colour.—General colour dark brown throughout with numerous small, irregular pale blotches on head and thorax and greenish intersegmental markings on the abdomen. Fore wings with pale brown markings in the apical half and in the region of the clavus, the four marginal markings having quite constantly a distinct Y-shape (Pl. 12, Fig. A).

Structure.—Head (Pl. 12, Fig. C) with the genae scarcely more than half as long as the vertex, distinctly separated at the base, divergent and bluntly rounded at the apex, which bears a pair of long setae. Frons represented by a small, triangular sclerite on the posterior aspect of the head. Antennae about twice as long as the width of the head. Thorax slightly pubescent, the prothorax (Pl. 13, Fig. A) with the form and position of the pleural suture, which is considered characteristic of the genus. Hind tibiae with a single well-developed spur at the base; with a single spur and a small comb of setae on the outer aspect and four spurs on the inner aspect at the apex. Tarsi with two large claw-like spurs at apex of first segment.

Fore wing (Pl. 12, Fig. A) with the form and venation characteristic of the genus, the branching dichotomous, with a distinct, closed pterostigma and with the apex of the wing broadly rounded; membrane beset throughout with punctations which are larger and darker in the pigmented areas; posterior border of the wing with four areas of small teeth (alar radulae; Pl. 12, Fig. B), these rendered inconspicuous by the pigmented areas in which they lie. Hind wings with the venation almost obliterated, formed only by a faint concentration of the small punctations with which the membrane is beset.

Genitalia of the female (Pl. 12, Fig. H) forming about one-third of the entire length of the expanded abdomen; dorsal plate strongly declivous, with but a slight point, scarcely exceeding the ventral plate, strongly hairy; gape of the valves small. Genitalia of male (Pl. 13, Fig. I) with the proctiger composed of a basal portion having strongly expanded and posteriorly angulate lateral lobes, and a cylindrical apical portion of about the same length; claspers strongly pyriform, tapering to the acute and posteriorly curved apex, the anterior margin with a series of strong setae, the inner face with a patch of small setae in the basal half.

Nymph (Pl. 16, Figs. H, I, J, L).—Described by Maskell as naked and active. Specimens representing the last instar are available. These are of the typical Psylliine form, the wing pads not produced forward and partially enclosing the head, the dorsum largely membranous and with numerous small sclerotic areas, the apical third of the dorsum of the abdomen being formed of a continuous plate, sectasetae not present. Length on slide 2 mm. Specific characters, separating it from the other available nymphs of Psylliine species, are to be found in the presence of a fringe of strong, slender setae along the margin of the wing pads and the posterior third of the abdomen, these setae (Pl. 16, Fig. I) not spatulate at the apex. The antennae are eight-segmented and rather long and slender. The circum anal pore ring (Pl. 16, Fig. J) outlines a small, cordate area and is composed of a single ring of quite small, elongate pores, enclosing an ill-defined ring of small, circular pores. Dorsum practically hairless. Empodium (Pl. 16, Fig. L) with a long, slender stalk bearing an expanded, membranous and somewhat radially striate lobe at the apex.

Notes.—We believe the identification of this species to be reasonably certain, certain features mentioned by Maskell, such as the Y-shaped markings of the fore wings being readily recognisable.

Psyllia albizziae, sp. n. (Pl. 12, Figs. E. F; Pl. 13, Figs. C. G.)

Specimens Examined.—Holotype, a male, and allotype and numerous paratypes, together with nymphs; from *Albizzia lophantha,* Governor's Bay, Canterbury (J. G. Myers and J. F. Tapley).

Colour.—A general pale green, with slightly brown markings on the head and thorax. Wings (Pl. 12, Fig. F) hyaline except the apical third with irregular, brownish maculations and the area anterior to the clavus with three such spots.

Structure.—Antennae slightly less than twice as long as width of head. Genae (Pl. 12, Fig. E) reduced to low, rounded prominences which are widely separated at the base by the ocellus and bear a single large subapical seta on the ventral side. Frons appearing as a distinct sclerite between the rather widely separated genae on the posterior (ventral) aspect. Head finely pubescent. Thorax with no distinctive features. Posterior tibia with a distinct basal spur, arrangement of the apical spurs variable, sometimes as in *P. acaciae* and sometimes with but three spurs on the inner face (Pl. 13, Fig. G). Tarsi of hind legs with two well-developed spurs at apex.

Genitalia of female (Pl. 12, Fig. I) forming scarcely a third of the total length of the expanded abdomen, the dorsal plate acutely tapering and slightly upturned at the apex, considerably exceeding the ventral plate; gape of the plates wide. Genitalia of male (Pl. 13, Fig. C) with the proctiger formed of a long, slender apical portion and a slightly shorter basal portion with broadly expanded, lateral lobes, the posterior margins of which are roundly convex and bear a distinct sclerotic spur; claspers characteristically formed, slender, tapering, and distinctly sickle-shaped, the inner face with a number of small, black, retrorse setae near the base.

Nymph.—In general very similar to the nymph of *P. acaciae*, differing conspicuously only in the form and distribution of the marginal setae. These are quite stout, and are distinctly spatulate at the apex (Pl. 16, Fig. H) and are present on the tibiae of the middle and posterior legs as well as along the margins of wing pads and abdomen.

Notes.—The head form of this species is more like that of the Liviinae than the Psylliinae, but the similarity of the nymphs and other characters indicate a close relationship to the other species here referred to *Psyllia*.

Psyllia apicalis, sp. n. (Pl. 12, Figs. D, J; Pl. 13, Fig. F).

Specimens Examined.—Holotype, a male, and allotype and several paratypes from " kowhai " (*Sophora tetraptera*) and without indication of host, Governor's Bay, Canterbury (J. G. Myers and J. F. Tapley).

Colour.—General colour dark brown, with lighter brown stripes on head and thorax. Wings (Pl. 12, Fig. D) typically with the basal three-fourths irregularly maculated with small brown spots and the apical fourth almost entirely pigmented by the fusion of many such spots. In some specimens the entire wing is rather uniformly maculated, without the apical band, and these specimens tend to be of a lighter colour than the others. There is a tendency toward an intergradation of the two types.

Structure.—Antennae slightly longer than width of head. Head form practically as in *P. acaciae* (Pl. 12, Fig. C). Thorax and head not pubescent. Posterior tibiae without a basal spur, apical spurs as in *P. acaciae*. Fore wing about two and a-half times as long as wide, very broadly rounded at apex; pterostigma large, closed; membrane thickly beset with punctations which are darker and more conspicuous in the pigmented areas; radulae entirely lacking.

Genitalia of female (Pl. 12, Fig. J) forming slightly more than a third of the total length of the expanded abdomen, the dorsal plate somewhat surpassing the ventral and with its apical third forming a rather acute process; valves gaping widely. Genitalia of male (Pl. 13, Fig. F) with the proctiger long and quite slender, somewhat flask-shaped; claspers pyriform, the apex acute and slightly curved posteriorly, their inner face with numerous small setae and with a cluster of larger setae on the basal half of the posterior margin.

Note.—It is possible that there are two species involved in our material because of the two types of wing pattern. However, all are structurally the same, and there is sufficient evidence of intergradation in the wing pattern to lend support to the belief that the differences are merely variants. The species is evidently rather close to *P. acaciae*.

Psyllia uncata, sp. n. (Pl. 12, Fig. K; Pl. 13, Fig. E).

Material Examined.—Holotype, a male, and allotype, several paratypes and two nymphs from *Acacia baileyana* and without indication of host, Governor's Bay, Canterbury (J. F. Tapley).

Colour.—Of a general dull reddish brown, the abdomen somewhat darker. Wings maculate with irregular light brown spots, in general similar to those of *P. albizziae,* but the maculations extending almost to the base of the wing and not confined to the apical third.

Structure.—Antennae slightly less than twice as long as width of head. Genae forming low, rounded lobes, intermediate in prominence between those of *P. acaciae* (Pl. 12, Fig. C) and *P. albizziae* (Pl. 12, Fig. E). Fore wing similar to that of *albizziae,* the membrane punctate throughout, the punctations more conspicuous in the pigmented areas; radulae present, but greatly reduced, apparently but three. Hind tibiae without spur at base, the apex with one spur on the outer side and four on the inner side. First segment of the hind tarsus with but one spur, this small.

Genitalia of the female (Pl. 12, Fig. K) scarcely more than a fourth of the entire length of the expanded abdomen, the dorsal plate but little exceeding the ventral, bluntly pointed and distinctly bent downward; gape of the valves large. Genitalia of male (Pl. 13, Fig. E) with the distal half of the proctiger cylindrical, the basal half strongly expanded into broad lateral lobes, the posterior margin of which bears a conspicuous and somewhat sclerotic hook-like lobe; claspers quite long, straight, and parallel-sided, with the apex curved posteriorly and produced into a small, sclerotic point, the inner face with three small, stout setae near the apex.

Nymph (Pl. 16, Fig. A).—Length on slide, 1.25 mm. Of the general Psylliine type. Distinguished from the others here dealt with by its complete lack of modified or conspicuous setae, the body being hairless except for a few very small setae. Circum-anal pore ring cordate as in *P. acaciae* (Pl. 16, Fig. K). Form of empodium indeterminable from the available material. Dorsal plates of thoracic region very small.

Notes.—This species is evidently rather closely related to *P. albizziae* and *P. uncatoides.* It is apparently not *P. acaciae-baileyanae* (Froggatt) described from the same host species from Australia.

Psyllia uncatoides, sp. n. (Pl. 13, Fig. D.)

Specimens Examined.—Holotype, a male, allotype and several paratypes from *Acacia melanoxylon,* Riwaka, Nelson.

Colour.—Pale reddish brown, with four white stripes on the thorax; abdomen paler and greenish beneath. Wings with mottlings practically identical with those of *P. albizziae* (Pl. 12, Fig. F) but perhaps less distinct.

Structure.—Antennae about one and a-third times as long as width of head. Head form practically identical with that of *P. acaciae* (Pl. 12, Fig. C), the genae with two subapical setae. Head and thorax slightly pubescent. Hind tibiae with a single well-developed spur at base; apex with one spur on outer side and four on inner. Posterior tarsi with but a single apical spur. Genitalia of female practically identical with those of *P. acaciae* (Pl. 12, Fig. H). Genitalia of male (Pl. 13, Fig. D) with the apical half slender and cylindrical, the basal half with strongly expanded lateral lobes that bear a conspicuous, non-sclerotic, hook-like lobe on the posterior border; claspers pyriform, curved posteriorly, the anterior margin with a conspicuous lobe near the base, this lobe beset with stout setae.

Notes.—The female of this species is practically identical with that of *P. acaciae,* differing in its general colour and in the pattern of the maculae on the fore wings. The male, on the other hand, is perhaps closest to *P. uncata,* from which it differs sharply in the form of the claspers.

Genus CTENARYTAINA, new genus.

Psylliine Chermidae in which the head is strongly deflexed, the genal cones present but short, being less than half as long as the vertex, the frons apparently entirely suppressed except for the anterior ocellus; antennae scarcely longer than the width of the head; wings with a closed pterostigma; posterior tarsi with the claw-like spines of the first segment very small; genitalia of the male always with a terminal lobe on the proctiger and with the inner face of the claspers beset in part with small, black, tubercle-like setae; pleural suture of the prothorax extending to the middle of the margin of the pronotum; *tibiae of the middle legs with a short, longitudinal, subapical comb of small setae.*

Type of the genus, *Rhinocola fuchsiae* Maskell. Three other species from New Zealand, here described as new, are included.

Notes.—On the basis of the existing literature this group of species might be regarded as belonging to the genus *Arytaina.* The type of the latter genus is not available to us, but there are at hand other species which have been referred to it. On the basis of these we believe the New Zealand group to merit recognition as distinct. The most precise character defining it is the presence of the small comb of setae on the middle tibiae, this being visible only under the higher power of the microscope. We have seen nothing of the sort in any other Psylliine forms.

KEY TO THE SPECIES OF CTENARYTAINA.

Females.

1. Dorsal valve of the genitalia beset along the ventral margin in its apical half with a fringe consisting of a double row of small, modified setae:

Ctenarytaina thysanura, sp. n.

Dorsal valve of genitalia without such fringe...............2

2. Genitalia elongate, sharply acute at the apex................3
Genitalia shorter, the dorsal plate relatively blunt at the apex:
Ctenarytaina clavata, sp. n.

3. Terminal blades of ovipositor serrate, gape of the valves slight:
Ctenarytaina fuchsiae (Maskell).
Terminal blades of ovipositor not serrate, gape of valves wide:
Ctenarytaina pollicaris, sp. n.

Males.

1. Proctiger with a tooth-like seta on posterior margin of basal lobe:
Ctenarytaina thysanura, sp. n.
Proctiger without such seta................................2

2. Proctiger with the basal portion produced laterally into a large lobe with acute apex....................................3
Proctiger with basal portion only slightly convex posteriorly:
Ctenarytaina fuchsiae (Maskell).

3. Clasper with a sclerotic, thumb-like basal lobe on the anterior margin:
Ctenarytaina pollicaris, sp. n.
Clasper entirely without such lobe: .
Ctenarytaina clavata, sp. n.

Ctenarytaina fuchsiae (Maskell). (Pl. 14, Figs. C, D, I.)

1890. *Rhinocola fuchsiae,* Maskell. *Trans. N.Z. Inst.,* 22, 162-164; Pl. 12, Figs. 13-25.

Previous Records.—From *Fuchsia excorticata* "in New Zealand."

Specimens Examined.—Several males and females from *Fuchsia excorticata,* Wellington; two females from Wilton's Bush, Wellington; three females from "konini" (*Fuchsia excorticata*), Governor's Bay, Canterbury (all J. G. Myers).

Colour.—General colour ranging from almost purplish to a general yellowish brown with darker markings; wings distinctly yellowish, not maculate.

Structure.—Length of pinned specimen to apex of wings 2 mm. Antennae but slightly longer than width of head. Head (Pl. 14, Fig. D) with the vertex and the genal cones in the same plane, practically vertical, smooth, the genae less than half as long as the vertex, their mesal margins almost approximate; frons represented only by median ocellus. Pronotum with the pleural suture (Pl. 13, Fig. B) reaching the middle of the lateral margin of the pronotum and not forked. Remainder of thorax presenting no distinctive characters. Middle legs with the distinctive comb of setae (Pl. 13, Fig. J) near the apex of the outer face of the tibia. Posterior tibiae without spur at base; with three small black spines at apex on one side and two on the other. Basal segment of posterior tarsi with two very small, claw-like spurs at apex.

Fore wings (Pl. 13, Fig. K) nearly three times as long as wide, regularly oval; pterostigma distinct; first marginal cell long and slender; membrane evenly pigmented and punctate throughout, the punctations arranged in a delicate lace-work (Pl. 13, Fig. M). Hind wings (Pl. 13, Fig. L) best with extremely minute and inconspicuous punctations; venation exceedingly faint, formed by a fold or thickening of the wing membrane with pigmentation.

Genitalia of the female (Pl. 14, Fig. C) composing a little less than half of the total length of the expanded abdomen, slender, and very acute, the dorsal plate considerably surpassing the ventral; ovipositor large, the apical blade dorsally serrate; gape of the valves but slight. Anal pore ring composed of a simple row of pores. Genitalia of the male (Pl. 14, Fig. I) with the proctiger divided into two parts, a large, basal portion which is expanded into slight lateral wings with convex posterior margin, and a small apical lobe, the whole almost hairless. Claspers moderately slender, regularly tapering to a somewhat acute apex, the inner face beset with numerous small, black, retrorse, tubercle-like setae.

Notes.—The identification of this species may be taken as certain. It is readily separable from the remaining species of the genus except that the female is somewhat similar to that of *C. pollicaris*. Compared directly the genitalia of these two females differ distinctly, but the differences are difficult to express verbally.

Ctenarytaina thysanura, sp. n. (Pl. 14, Figs. B, F, H; Pl. 16, Figs B, C, D.)

Specimens Examined.—Holotype, a female, allotype and several paratypes, and also nymphs from *Boronia* sp., " from Melbourne," Dunedin.

Colour.—General colour yellowish brown with darker markings; abdomen striped with black; wings yellowish.

Structure.—In general quite close to *C. fuchsiae*, but differing in the following particulars. Antennae slightly shorter than width of head. Head (Pl. 14, Fig. F) apparently slightly different in form, the occiput more concave. Genitalia of female (Pl. 14, Fig. B) very long and slender; dorsal plate beset along the apical half of its ventral margin with a fringe composed of two rows of small, modified setae; gape of the valves wide; the ovipositor with its parts very large, the palps tranversely striate. Genitalia of male likewise very distinctive (Pl. 14, Fig. H), the proctiger with a slender apical lobe, the basal portion strongly expanded into lateral lobes, which bear a conspicuous, stout, thorn-like seta on their posterior border; claspers slender, tapering, the posterior margin sinuate, the inner face with areas of small, stout setae.

Nymph (Pl. 16, Figs. B, C, D).—Length on slide, 1.25 mm. Of the ordinary Psylliine type, with the following distinctive details. Antennae rather short and stout, eight-segmented. Dorsal plates of the thoracic region but two, these large. Abdomen with the apical half of the dorsum included within a single plate. Body destitute of all but a very few extremely small setae, except for a fringe of small, hastate setae about the margin at the apex (Pl. 16, Fig. D). Circum-anal pore ring (Pl. 16, Fig. C) small, very broadly cordate, composed of a single ring of pores enclosing an irregular ring of obscure, circular pores. Empodium distorted in all the available specimens.

Notes.—The characters of this species that are most of all distinctive are of a sort which would almost certainly be entirely overlooked in the conventional pinned material.

Ctenarytaina clavata, sp. n. (Pl. 14, Figs. E, G.)

Specimens Examined.—Holotype, a male, allotype and numerous paratypes from "manuka" (*Leptospermum scoparium*); Wellington Botanical Gardens; one specimen "on grass," Aramoho.

Colour.—Ranging from head and thorax yellowish, abdominal sclerites and genitalia dark brown, to head and thorax brick red with abdomen reddish brown and genitalia dark brown.

Structure.—Similar to the preceding species except in the following details. Antennae slightly longer than width of head. Genitalia of female (Pl. 14, Fig. E) constituting about one-third of the total length of the abdomen, comparatively stout, the dorsal plate not sharply acute and but little exceeding the ventral, the gape of the valves large. Genitalia of the male (Pl. 14, Fig. G) very distinctive, the proctiger large, with a small, cylindrical apical lobe, the basal portion produced into large lateral wings which are produced into an acute apex; claspers strongly clavate in form, beset on the inner face with small, black, tuberculate setae over the apical half and in a small basal cluster.

Notes.—This is apparently closest to the following species.

Ctenarytaina pollicaris, sp. n. (Pl. 14, Figs. A, J.)

Specimens Examined.—Holotype, a male, and allotype and several paratypes from "manuka" (*Leptospermum ericoides*), Aramoho, and Orongo-orongo, Wellington; without indication of host, Catchpole, Wellington.

Structure.—Differing from *C. Clavata* only in the following details. Genitalia of female (Pl. 14, Fig. A) with the valves elongate and acute. Genitalia of the male (Pl. 14, Fig. J) much as in *clavata,* but the claspers with a distinct, black, thumb-like process at the base on the anterior margin.

Subfamily PAUROPSYLLINAE.

Genus PAUROPSYLLA, Rübsamen.

This genus, as understood by Crawford, includes Pauropsylline forms in which the posterior legs are longer than the middle and the posterior coxae have the coxal spur present although short; fore wings transparent, the veins branching dichotomously, the first marginal cell not narrow and long; antennae not longer than the width of the head.

With this characterisation the species here to be dealt with agrees only in part. It lacks entirely the usual posterior spur of the hind coxae, and is thus similar to but one other known species of the Chermidae, *Apsylla cistellata* (Buckton), but it cannot belong to the genus *Apsylla,* at least as now defined, because of the large hind legs. The characteristics of the fore wing are somewhat those of *Paurocephala,* but specimens of the type of the latter genus are at hand, and with that it is certainly not congeneric. We are assigning the species to *Pauropsylla* chiefly because of its apparent resemblance to *P. verticis* Crawford and *P. depressa* Crawford, since we do not have at hand material which will permit us to discuss the question of generic groups in his subfamily.

In common with the two species mentioned, the species at hand lacks entirely the median furrow of the vertex, which in apparently all other Chermids is present, extending from the median ocellus to the occiput. Its absence gives to the face of the insect a most unusual appearance. That the three species which lack this furrow are closely related seems probable, whether or not they belong to the genus *Pauropsylla*.

Pauropsylla myersi, sp. n. (Pl. 15, Figs. A, C, B, F, K, L, M, O, P.)

Specimens Examined.—Holotype, a female, and allotype, three paratype females and three paratype males from "kamahi" (*Weinmannia racemosa*), York Bay, Wellington (J. G. Myers).

Colour.—General colour a dark brown, with the face, pronotum, areas at base of wings, and the scutellum pale yellow; wings hyaline, with the veins and pterostigma dark brown. Length of pinned specimen to apex of wings 2.8 mm.

Structure.—A robust species, with the thorax short and broad, the head reflexed beneath the prothorax and exceedingly short, dorsally crescentic in outline, slightly exceeding in width the very short prothorax which is received into its excavated posterior border.

Antennae (Pl. 15, Fig. B) scarcely as long as the width of the head, penultimate segment bearing one fleshy spine and the last segment with two such spines, these about as long as the segment from which they arise. Head (Pl. 15, Fig. C) of a peculiar type; eyes prominent, on the dorsal side not received into the epicranium; median furrow of the vertex entirely lacking; frons represented only by the median ocellus; genae somewhat swollen; clypeus relatively very small; rostrum comparatively enormous (Pl. 15, Fig. L), nearly twice as long as the anterior coxae. Setae on the head sparse, very small.

Prothorax (Pl. 15, Fig. L) with the pleurites greatly reduced, the pronotum extending far down the sides of the body. Pterothorax, while rather short, presenting no unusual developments. Posterior coxae (Pl. 15, Fig. K) while rather small, still greatly exceeding the middle coxae in size, but showing no trace of the posterior spur. Posterior legs with the femur only slightly longer than that of the middle legs, but with the tibia elongate, being nearly one and a-half times as long as the femur. Posterior tibia with a crowded row of black spines (Pl. 15, Fig. O) at the apex and without a basal spine. Apices of the other tibiae with a small, transverse comb of setae on one side. Tarsi (Pl. 15, Fig. M) all with the first segment swollen, the second long and slender, those of the posterior legs without claw-like spines on the basal segment.

Fore wings with the membrane beset toward the apex with inconspicuous punctations; pterostigma strongly developed but small; medial-cubital petiole long, the base of the cubitus very short; marginal cells long and slender. In some specimens an abnormality is present in the form of an extra vein extending from M to Cu_1, forming a small extra cell. That this is an abnormality—or at least a mere variation—is clearly indicated by the fact that the vein may be present in but one wing, or may differ in position on opposite sides of the same specimen. Hind wings with the venation obsolete except for the costa, the base of the main veins and the first anal; membrane uniformly beset with small punctations.

Abdomen with but the first five pairs of spiracles present instead of the seven pairs usual in the family; tergites and sternites strongly sclerotic, the spiracles borne either in very small plates or in the ends of the tergites. Genitalia of the female (Pl. 15, Fig. F) of a very peculiar form, the valves apparently being fused throughout the greater part of their length to form a solid segment, which close to its apex is suddenly and greatly constricted, leaving a very short and very small apical portion that envelopes the apices of the parts the ovipositor; apodemes of the ovipositor very long, extending through at least the two segments anterior to the genitalia; anal pore ring composed of two or three rows of small, roughly circular pores. Genitalia of the male (Pl. 15, Fig. P) relatively very small, the proctiger short and broad, the claspers slender, with the posterior margin almost straight, the anterior margin parallel through its basal half and then converging to an acute point; inner face with two rows of stout, black, tubercle-like setae in the apical half.

Notes.—We take pleasure in naming this unusual species for Dr J. G. Myers, to whom we are indebted for the opportunity of preparing this paper.

Genus METAPHALARA Crawford.

1925. Crawford, Broteria, *Série Zoológica* 22, 60.

We are utilising this genus for the reception of a single New Zealand species of doubtful position of which we have but two females. The genus has as its type a South American species, *Metaphalara cannela* Crawford, and is characterised by its author as follows:—
"Head not much deflexed; vertex broader than long, turned down in front between antennal bases; genal cones wanting; frons visible from beneath as a long, narrow sclerite between genae, with anterior ocellus at its front end; clypeus elongate, piriform. Eyes more or less hemispherical. Antennae moderately long, about twice as long as width of head or longer, rather stout.

"Thorax not much arched. Hind tibiae with several small spines at apex and basal tarsus with two black claws. Fore wings membranous, more or less hyaline, broadly rounded at apex, with a pterostigma.

"Male anal valve produced caudad into two finger-like processes in *Aphalara.*"

To the genus Crawford has referred two other species, *Paurocephala ilicis* (Ashmead) and *Paurocephala spegazziniana* (Lizer), the former from North and the latter from South America. He states that the genus is "more or less midway between Aphalarinae and Pauropsyllinae in its relationship to other genera." With the characterisation as given by Crawford our New Zealand species agrees rather well.

Metaphalara zealandica, sp. n. (Pl. 15, Figs. E, G, H, I, J, N.)

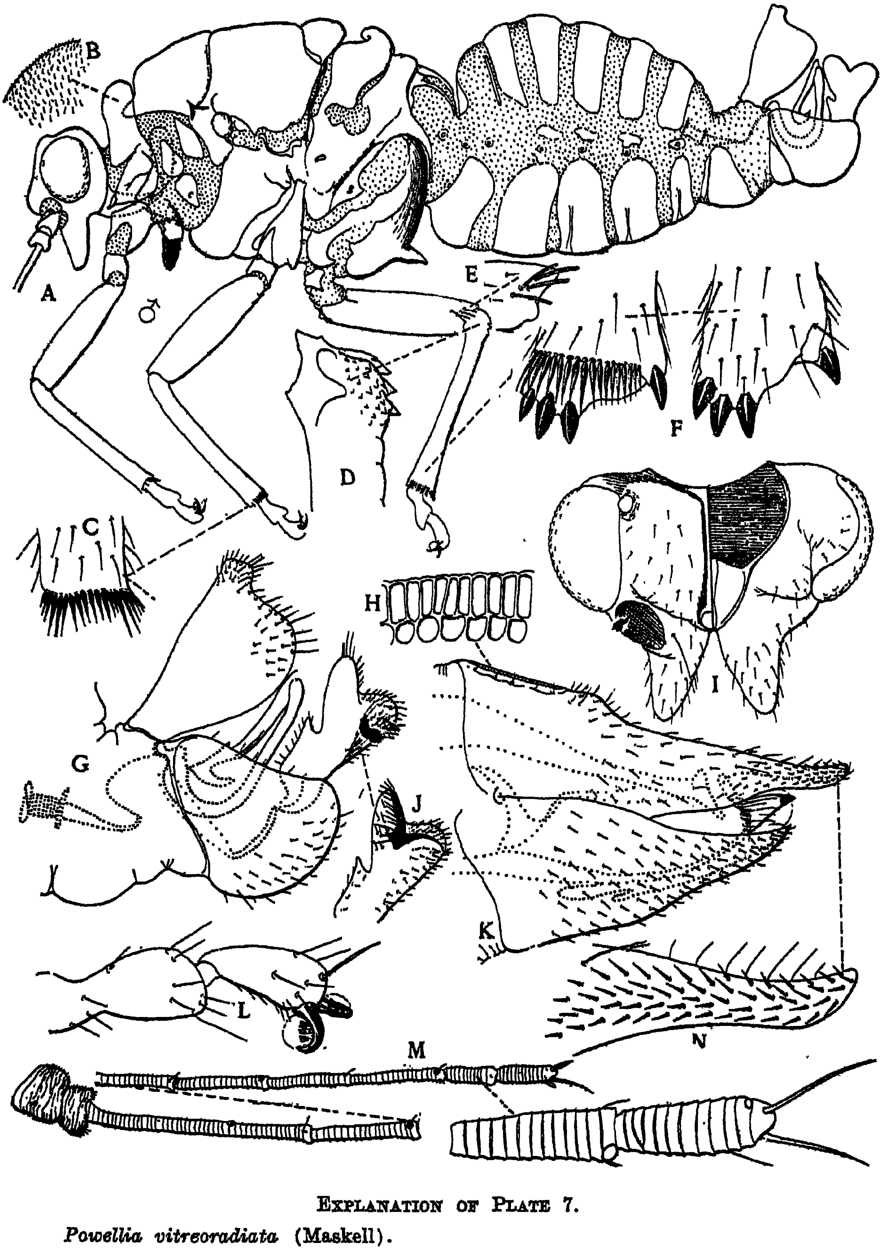
Specimens Examined.—Two females, the holotype from Arthur's Pass (J. G. Myers) and a paratype from Bluecliff.

Colour.—No notes available. Wings very slightly brownish, the fore wings with a slightly darker brown border along the posterior margin of the clavus, the hind wings with a similar border along the costa.

Structure.—Antennae about twice as long as width of head, rather slender, presenting no unusual features. Head (Pl. 15, Fig. E) with the characteristics of the genus; anterior ocellus very obscure; anterior margin showing a slight tendency toward the birostrate appearance which is more or less characteristic of the Cherminae (Carsidarinae).

Thorax presenting nothing unusual. Pleurites of prothorax normally developed, the pleural suture Y-shaped. Posterior tibia without a spine at the base and with several small, black spines at apex (Pl. 15, Fig. N). Posterior tarsi with two black, claw-like spines at apex. Fore wings (Pl. 15, Fig. D) with the membrane sparsely beset with inconspicuous punctations; pterostigma long and slender. Posterior wings with the membrane beset with punctations; venation very obscure; formed only a slight concentration of the punctations; radial sector and media and the anal vein alone evident.

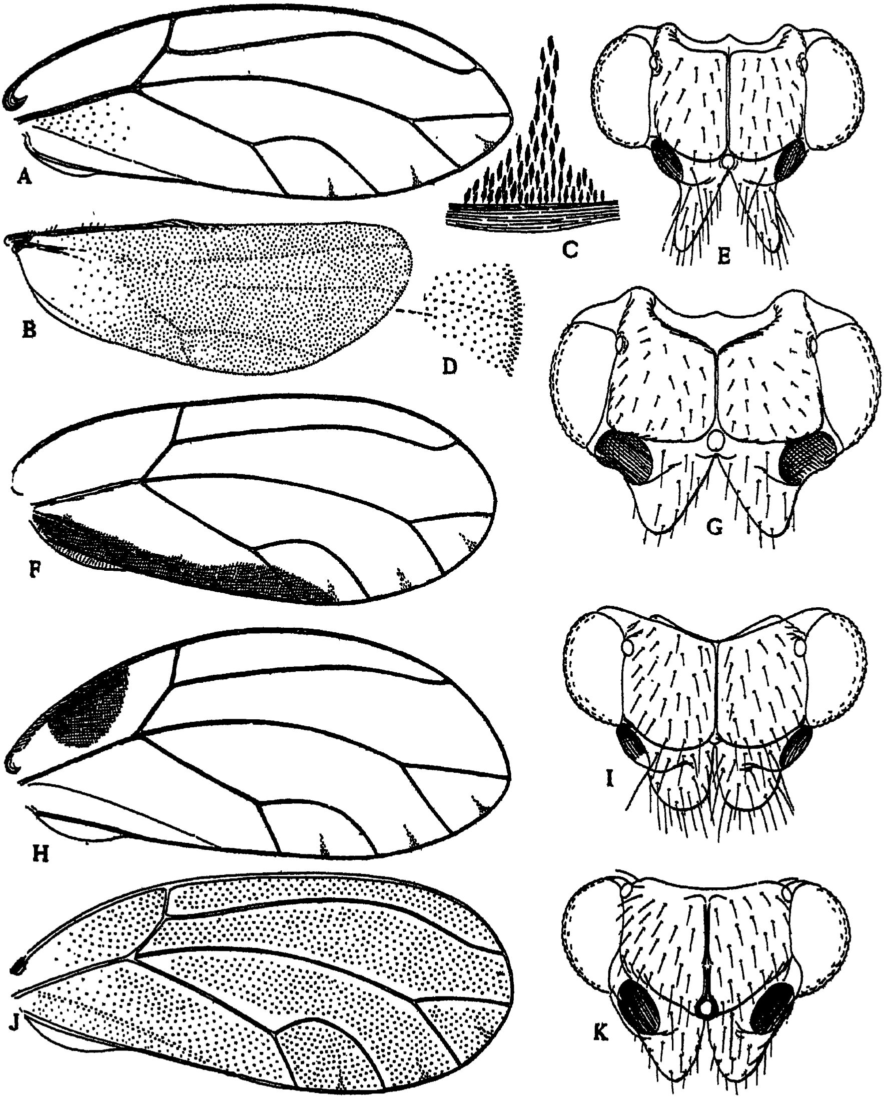
Abdomen with its plates weakly sclerotic, but presenting no unusual features except in the genitalia. Genitalia (Pl. 15, Fig. G) forming scarcely more than a fourth of the length of the expanded abdomen, the dorsal plate abruptly declivous and produced into a slender, acute, apical process which is roughly serrate at the tip (Pl. 15, Fig. I), considerably exceeding the ventral plate; gape of the valves slight. Ovipositor with the apices of its lateral pieces expanded, diagonally truncate and serrate (Pl. 15, Fig. J) and with the palps transversely striate.



Explanation of Plate 7.

Powellia vitreoradiata (Maskell).

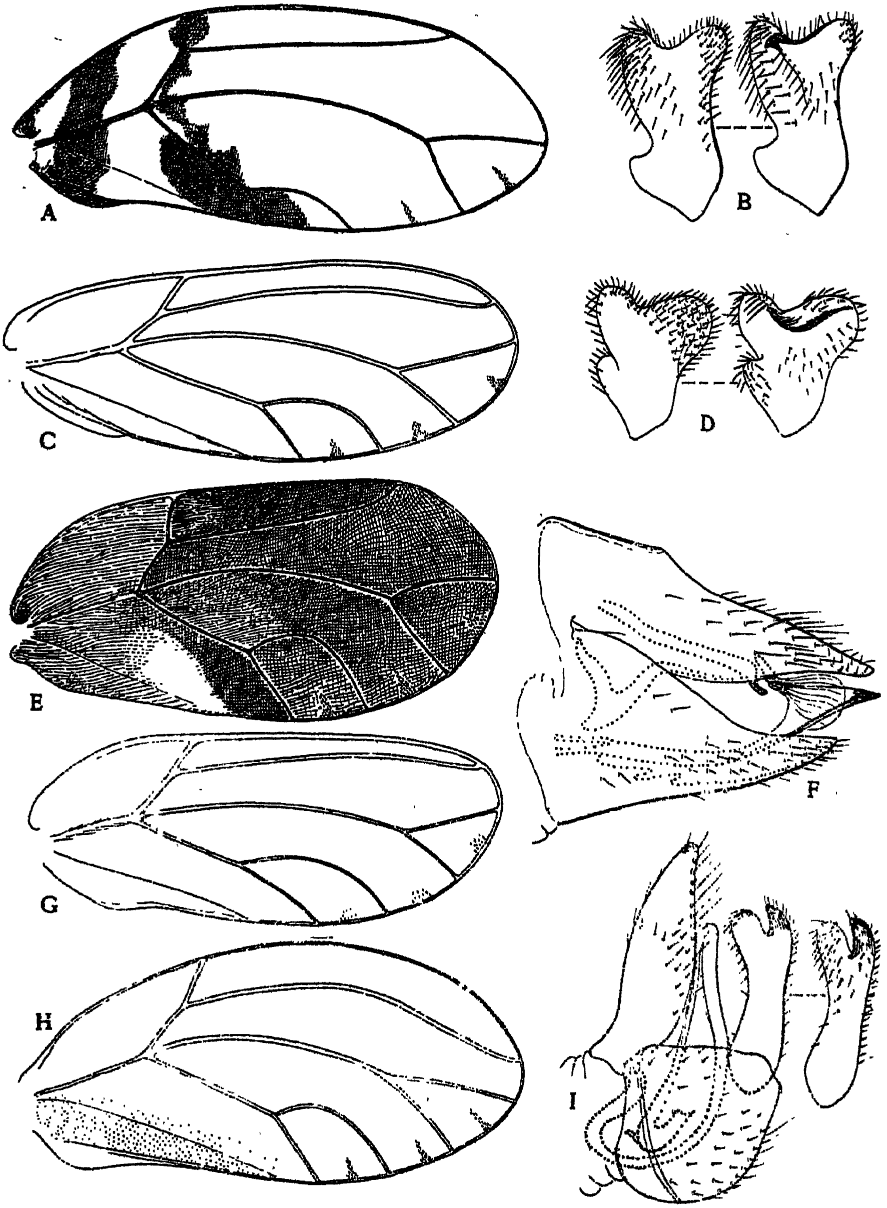
A. Lateral aspect of male.
B. Markings of derm of thorax.
C. Apex of tibia of middle leg.
D. Base of tibia of posterior leg.
E. Apex of femur of posterior leg.
F. Outer and inner aspects of apex of posterior tibia.
G. Genitalia of male.
H. Portion of circum-anal pore ring of adult female.
I. Head, left side dorsal, right side ventral.
J. Inner face of clasper of male.
K. Genitalia of female.
L. Posterior tarsus.



EXPLANATION OF PLATE 8.

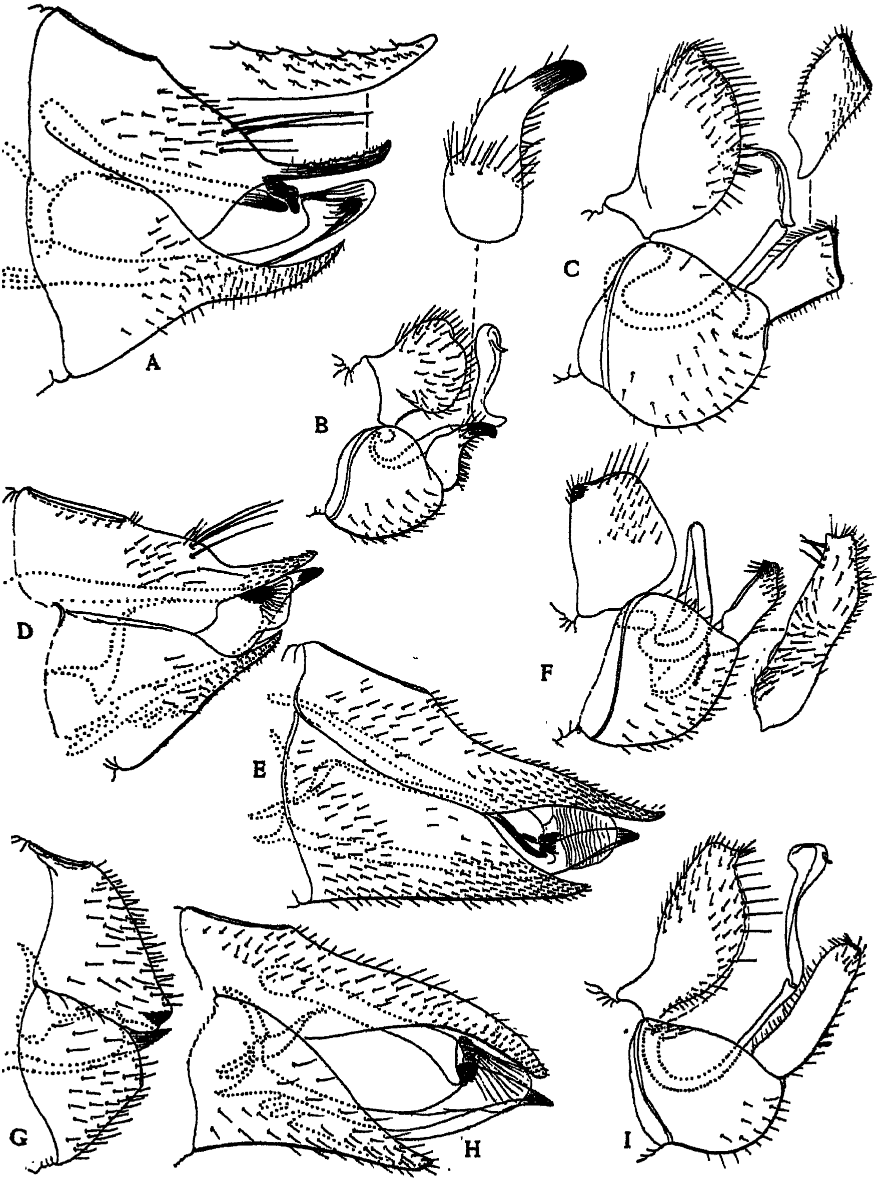
A. *Powellia vitreoradiata* (Maskell), fore wing.
B. The same, hind wing.
C. The same, alar radula.
D. The same, detail of hind wing.
E. *Powellia subacuta*, sp. n., head.
F. *Powellia falcata*, sp. n., fore wing.
G. *Powellia colorata*, sp. n., head.
H. *Powellia emarginata*, sp. n., fore wing.
I. *Powellia fasciata*, sp. n., head.
J. *Powellia bifida*, sp. n., wing.
K. *Powellia curta*, sp. n., head.

Plate 9.



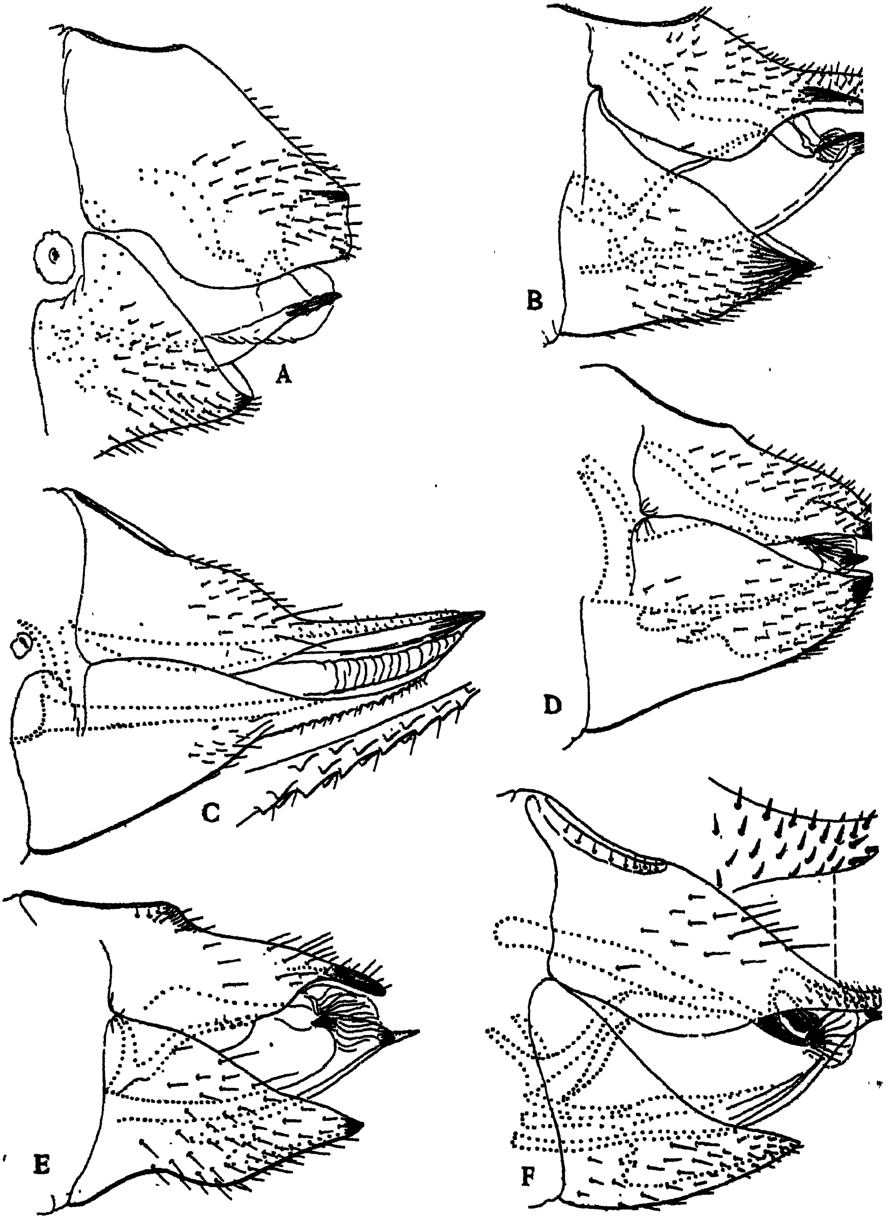
Explanation of Plate 9.

A. *Powellia fasciata*, sp. n., fore wing of paratype.
B. *Powellia falcata*, sp. n., claspers of male.
C. *Powellia decurvata*, sp. n., fore wing.
D. *Powellia emarginata*, sp. n., claspers of male.
E. *Powellia colorata*, sp. n., fore wing.
F. *Powellia emarginata*, sp. n., genitalia of female.
G. *Powellia obfusca*, sp. n., fore wing, pigmentation not indicated.
H. *Powellia acuta*, sp. n., fore wing.
I. *Powellia bifida*, sp. n., genitalia of male.



EXPLANATION OF PLATE 10.

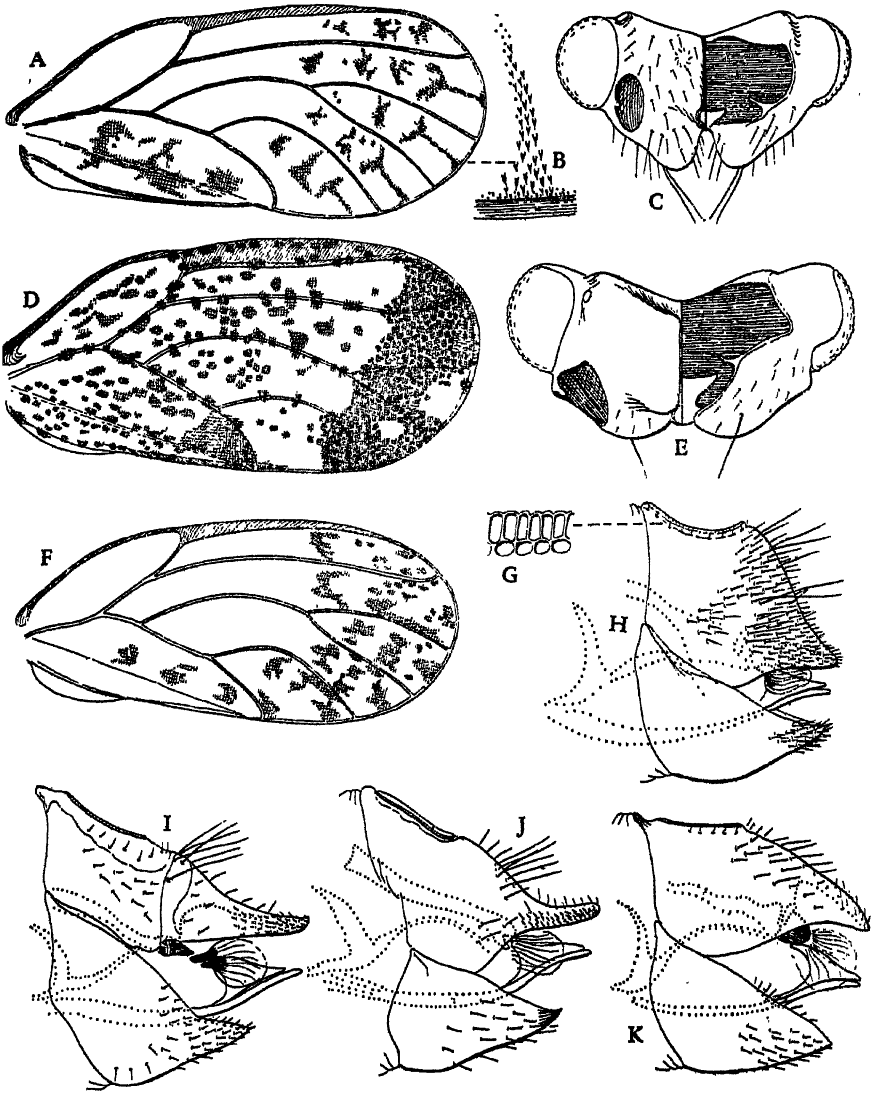
A. *Powellia acuta*, sp. n., genitalia of female and detail of same.
B. *Powellia curta*, sp. n., genitalia of male and inner face of clasper.
C. *Powellia acuta*, sp. n., genitalia of male and inner face of clasper.
D. *Powellia subacuta*, sp. n., genitalia of female.
E. *Powellia bifida*, sp. n., genitalia of female.
F. *Powellia subacuta*, sp. n., genitalia of male and inner face of clasper.
G. *Powellia curta*, sp. n., genitalia of female.
H. *Powellia decurvata*, sp. n., genitalia of female.
I. *Powellia decurvata*, sp. n., genitalia of male.



EXPLANATION OF PLATE 11.

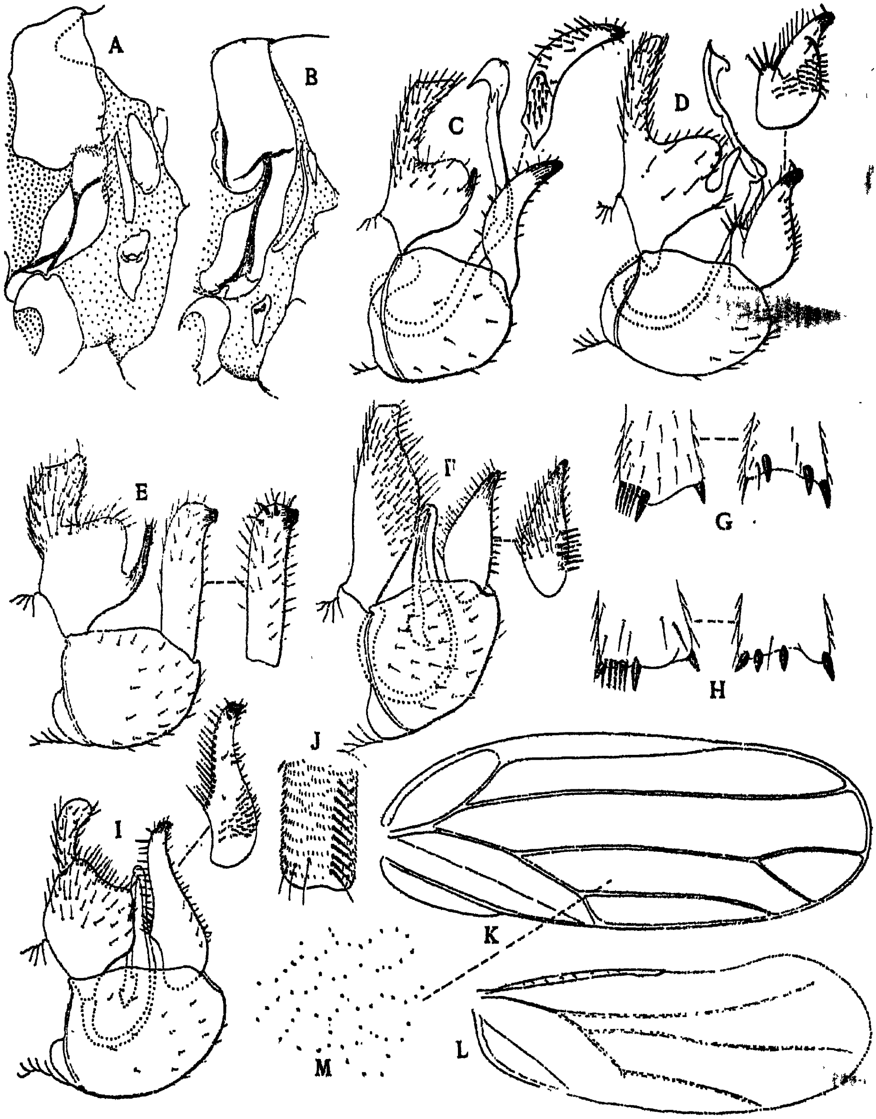
Genitalia of females of:

A. *Powellia fasciata*, sp. n.
B. *Powellia colorata*, sp. n.
C. *Powellia styligera*, sp. n.
D. *Powellia equalis*, sp. n.
E. *Powellia irregularis*, sp. n.
F. *Powellia obfusca*, sp. n.



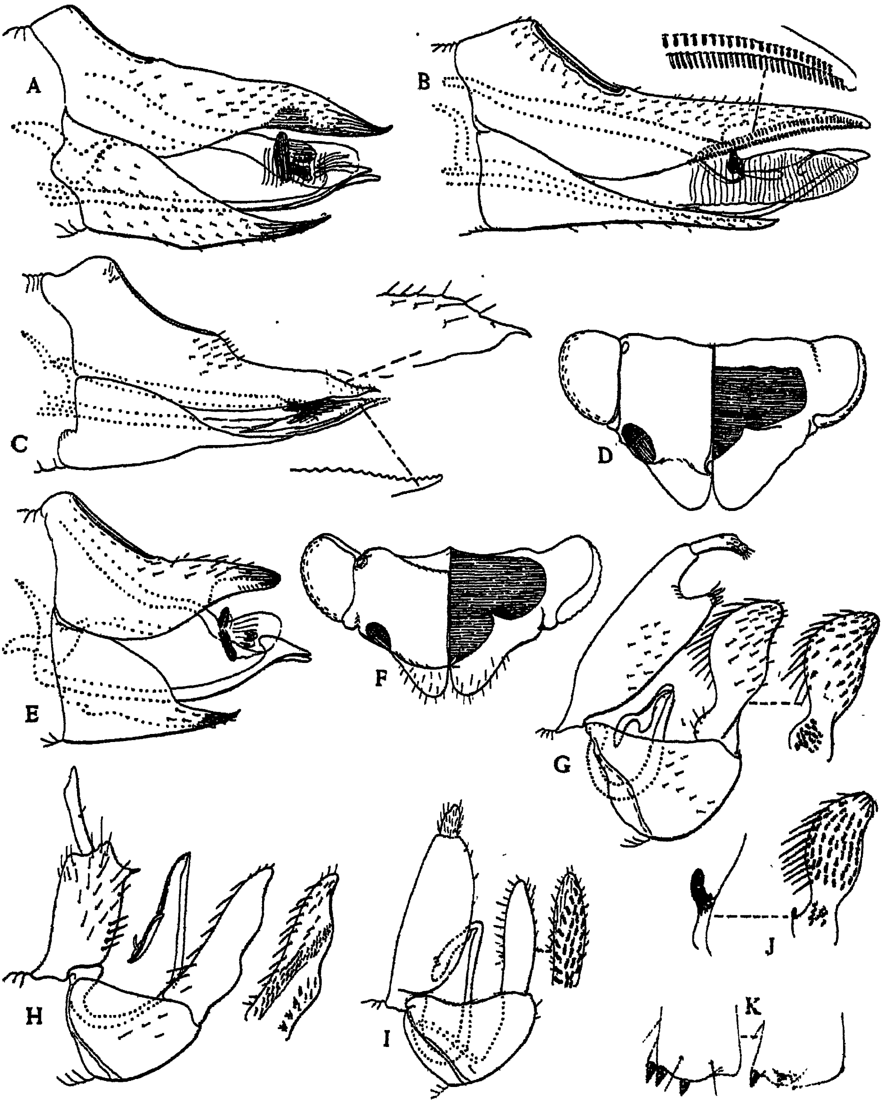
EXPLANATION OF PLATE 12.

A. *Psyllia acaciae* (Maskell), fore wing.
B. Alar radula of same.
C. Head of same.
D. *Psyllia apicalis*, sp. n., fore wing.
E. *Psyllia albizziae*, sp. n., head.
F. Fore wing of same.
G. *Psylliae acaciae* (Maskell), portion of circum-anal pore ring.
H. Genitalia of female of same.
I. *Psylliae albizziae*, sp. n., genitalia of female.
J. *Psyllia apicalis*, sp. n., genitalia of female.
K. *Psyllia uncata*, sp. n., genitalia of female.



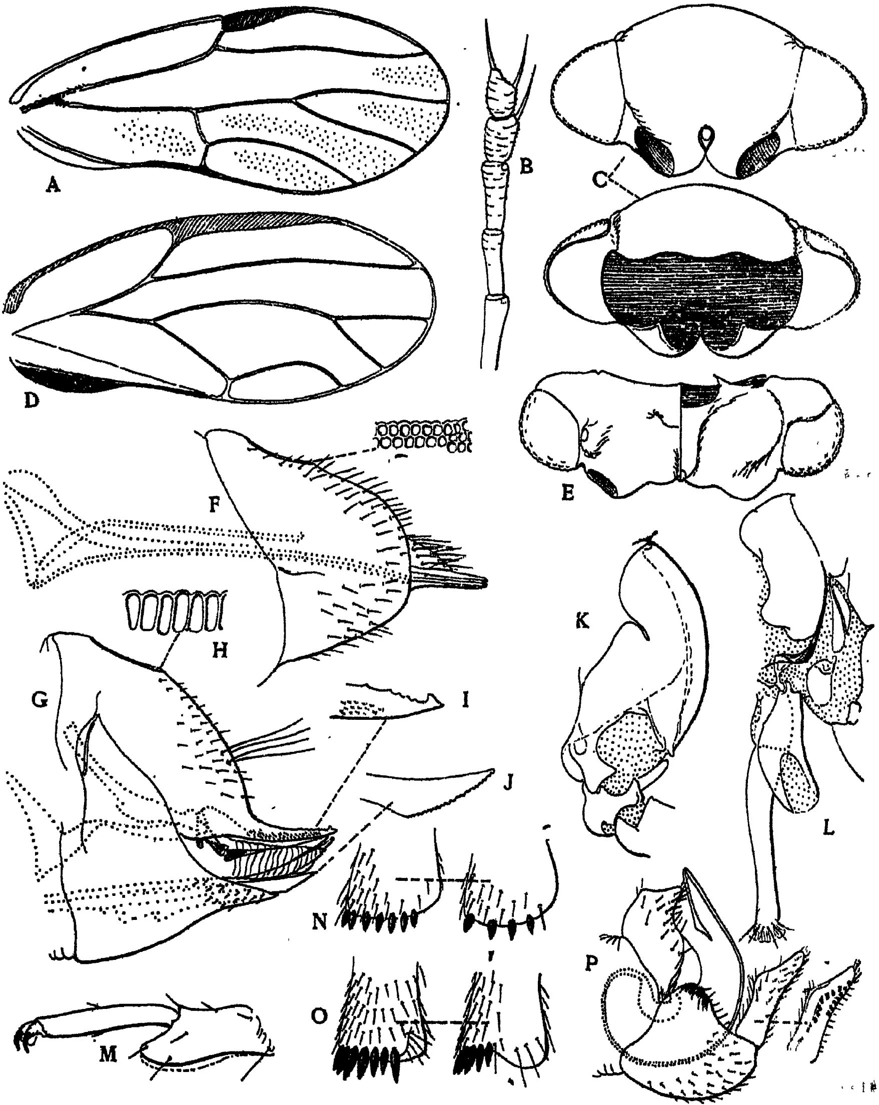
EXPLANATION OF PLATE 13.

A. *Psyllia acaciae* (Maskell), lateral aspect of prothorax.
B. *Ctenarytaina fuchsiae* (Maskell), lateral aspect of prothorax.
C. *Psyllia albizziae*, sp. n., genitalia of male and inner face of clasper.
D. *Psyllia uncatoides*, sp. n., genitalia of male and inner face of clasper.
E. *Psyllia uncata*, sp. n., genitalia of male and inner face of clasper.
F. *Psyllia apicalis*, sp. n., genitalia of male and inner face of clasper.
G. *Psyllia albizziae*, sp. n., apex of posterior tibia.
H. *Psyllia acaciae*, sp. n., apex of posterior tibia.
I. Same, genitalia of male and inner face of clasper.
J. *Ctenarytaina fuchsiae* (Maskell), comb of setae at apex of middle tibia.
K. Same, fore wing.
L. Same, hind wing.
M. Same, detail of arrangement of punctations on fore wing.



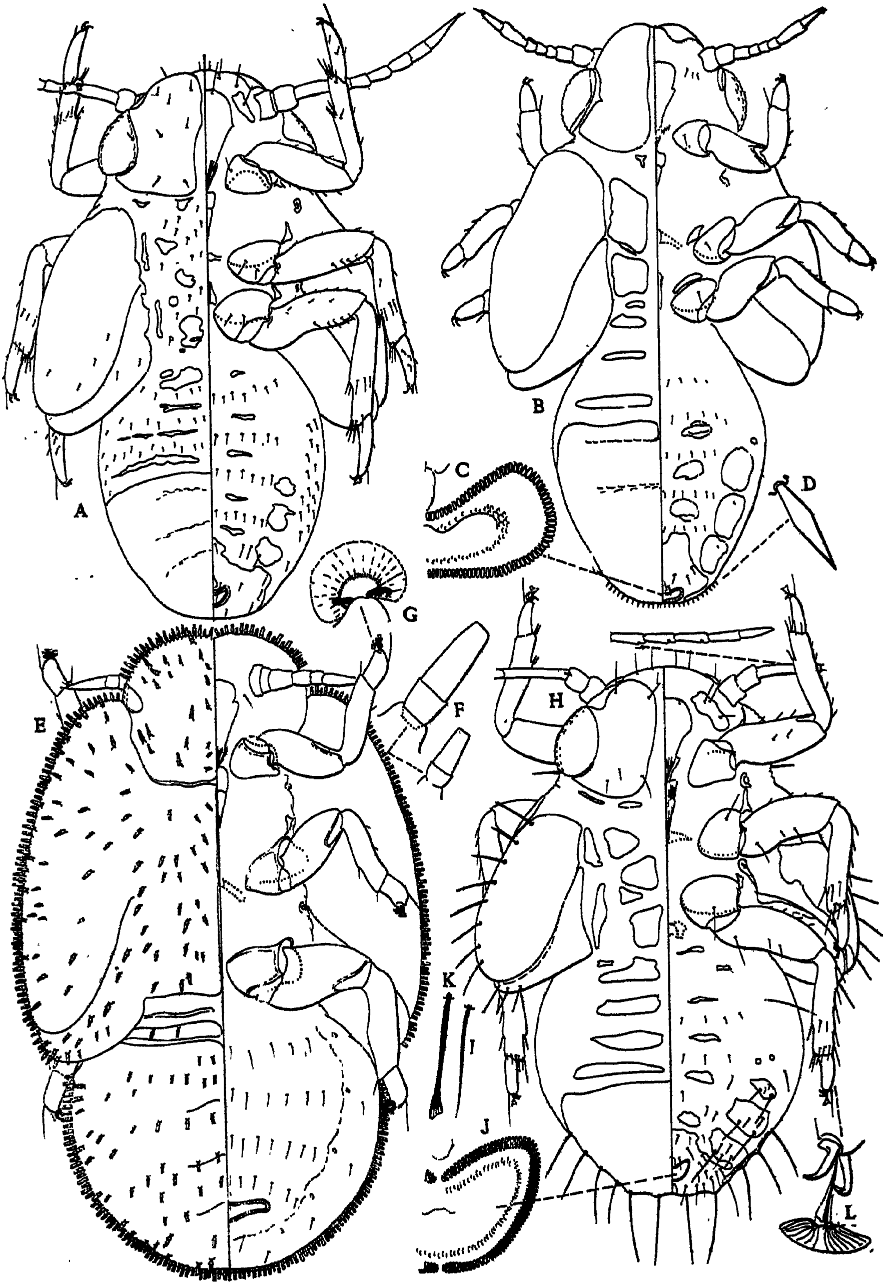
EXPLANATION OF PLATE 14.

A. *Ctenarytaina pollicaris*, sp. n., genitalia of female.
B. *Ctenarytaina thysanura*, sp. n., genitalia of female and detail.
C. *Ctenarytaina fuchsiae* (Maskell), genitalia of female and details.
D. Same, head.
E. *Ctenarytaina clavata*, sp. n., genitalia of female.
F. *Ctenarytaina thysanura*, sp. n., head.
G. *Ctenarytaina clavata*, genitalia of male and inner face of clasper.
H. *Ctenarytaina thysanura*, sp. n., genitalia of male and inner face of clasper.
I. *Ctenarytaina fuchsiae* (Maskell), genitalia of male and inner face of clasper.
J. *Ctenarytaina pollicaris*, sp. n., inner face of clasper and detail.
K. *Ctenarytaina fuchsiae* (Maskell). apex of posterior tibia.



EXPLANATION OF PLATE 15.

A. *Pauropsylla myersi*, sp. n., fore wing.
B. Same, apex of antenna.
C. Same, cephalic and caudal aspects of head.
D. *Metaphalara zealandica*, sp. n., fore wing.
E. Same, head.
F. *Pauropsylla myersi*, sp. n., genitalia of female and detail of pore ring.
G. *Metaphalara zealandica*, sp. n., genitalia of female.
H. Same, detail of circum-anal pore ring.
I. Same, apex of dorsal plate of genitalia.
J. Same, apex of blade of ovipositor.
K. *Pauropsylla myersi*, sp. n., posterior coxa.
L. Same, lateral aspect of prothorax and rostrum.
M. Same, posterior tarsus.
N. *Metaphalara zealandica*, sp. n., apex of posterior tibia.
O. *Pauropsylla myersi*, sp. n., apex of posterior tibia.



Nymphs of: EXPLANATION OF PLATE 16.

A. *Psyllia uncata*, sp. n.
B. *Ctenarytaina thysanura*, sp. n.
C. Same, detail of circum-anal pore ring.
D. Same, seta from apex of abdomen.
E. *Powellia vitreoradiata* (Maskell).
F. Same, sectasetae.
G. Same, empodium.

Notes on the Geology and Geomorphology of the Coast Between Napier and Castlepoint.

By L. C. King, M.Sc., F.G.S., Victoria University College, Wellington.

[*Read before Wellington Philosophical Society, 10th June, 1931; received by Editor, 31st July, 1931.*]

CONTENTS.

Introduction.
Clifton to Cape Kidnappers.
Cape Kidnappers to Waimarama.
Waimarama to Black Head.
Black Head to Porangahau.
Porangahau to Castlepoint.
Conclusion.

INTRODUCTION.

AFTER the conclusion of some previous work on the coast from Castlepoint to Wellington the writer felt strongly impelled to examine the stretch of coastline from Napier to Castlepoint, expecting to find there raised terraces similar to those already examined south of Castlepoint and those recorded by other writers from north of Gisborne. Accordingly, in company with Mr W. K. McGavin, he made the trip in November-December, 1930. The coastline throughout most of the length examined proved most disappointing, only one high-level terrace of any magnitude being in evidence and most of the land facing the sea consisting of landslip. Thus only a series of notes on various portions of the coast (mainly with reference to the present shoreline) are here presented.*

The thanks of both wayfarers are here gratefully tendered to the managers of the following stations for very welcome assistance or accommodation:—Haupouri, Te Apiti, Pourerere, Sir Percy Hunter's, and Aohanga.

CLIFTON TO CAPE KIDNAPPERS (5 miles).

From Clifton to Cape Kidnappers the coast cuts across the strike of the country so that, as the beds have a westerly dip, a descending sequence is observed on travelling towards the Cape (Pl. 17, Fig. 1). The rocks consist, in the upper part, of thick beds (20-60 feet) of coarse conglomerate alternating with beds of mudstone of about the same thickness. These conglomerates are composed of rounded, even-graded pebbles of greywacke some 3 or 4 inches in diameter with a ferruginous cement; while the mudstones contain much fragmentary carbonaceous material, embedded tree stumps, and small veins of gypsum. *Chione Stutchburyi*, often a brackish

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*No notes relative to the coast from Napier to Clifton are included here, as it is intended to deal fully with this portion at a later date.

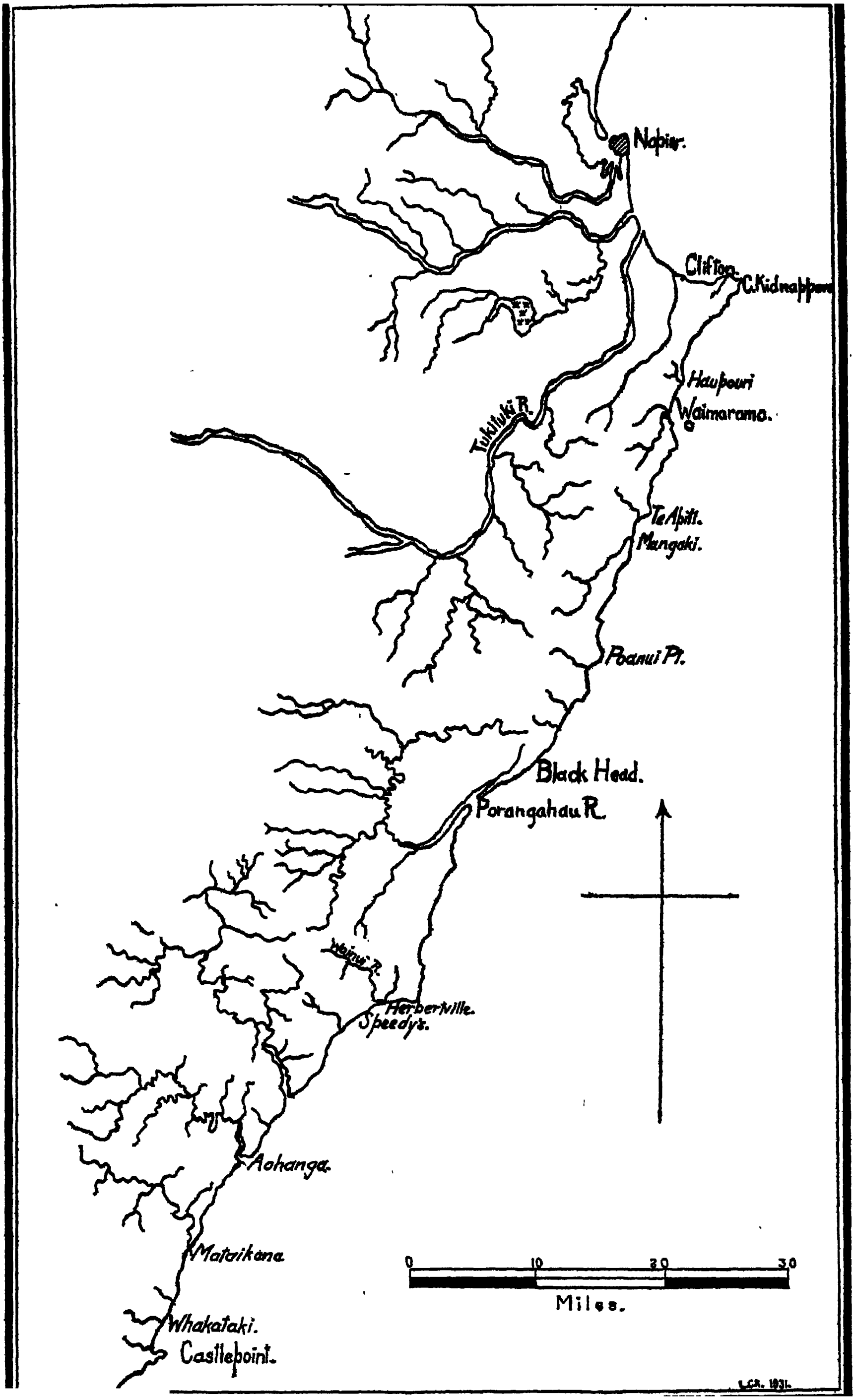

FIG. 1.—Sketch map of the East Coast of the North Island, N.Z., from

water fossil, also occurs in the mudstones at some horizons. The whole facies therefore presents the appearance of having been laid down in a partially enclosed sheet of water at some time during the Upper Pliocene or Pleistocene (vide McKay, 1887, p. 192). This area of deposition may be regarded as an ancestral, more extensive Heretaunga basin, in many respects akin to the infilled area known to-day as the Heretaunga Plain.

To the east, below these shallow-water-beds, succeed yellow sandy strata which appear to have been laid down under normal marine conditions preceding the formation of the basin. Several small faults in these beds may be observed in the coastal section. Half a mile west of Black Reef is an erosion-break between the upper, yellow sandy beds and well consolidated, dark grey sandy beds of Pliocene age, containing *Pecten triphooki* and *Glycymeris mahiana.* The unfossiliferous yellow sands near the contact often contain fragments of the lower beds with their characteristic fossils. Cape Kidnappers is cut from Tertiary mudstones, which frequently contain elongated, cylindrical concretionary bodies, usually with a hollow tube down the centre (Pl. 18, Fig. 1).

Thus normal marine deposition continued in this region till about the close of the Pliocene, when movements due to the Kaikoura Orogeny instituted a local basin of deposition in which shallow water deposits were laid. Part of this depressed area now forms the Heretaunga Plain.

From Clifton to Black Reef the coast is backed by splendid cliffs 300 feet to 400 feet high, occasionally broken by gorges with vertical walls, where small streams emerge from the country in rear. At the foot of the cliffs is a small shingle beach seaward of which the shore zone consists of clean coarse sand. In moderately rough weather the sea still reaches the base of the cliffs, and the shore is for the most part kept clear of slip material. Beyond Black Reef a wide, firm, sandy beach extends halfway to Cape Kidnappers, to be succeeded by a rock bench, 2 or 3 feet above high water mark, cut in mudstone to a width of 6 yards, at the foot of the mudstone cliffs. This is, no doubt, a storm-wave platform similar to those described by Bartrum (1924, p. 493) from West Auckland.

Between Clifton and Cape Kidnappers an arched, high-level terrace, now deeply dissected by numerous streams, forms the most prominent feature of the landscape. This platform, some six miles long and with an average width of one mile, is of particular interest, for it is the only remnant of a raised coastal terrace at any considerable height above sea-level throughout the whole of the coast described in this paper. Owing to the arching to which it has been subjected, the height along the old strandline at the rear varies from a maximum of about 600 feet at a point two miles south-east of Clifton to some 350 feet at the Cape Kidnappers end. It also descends westward a little towards Clifton. To the west, the nature of the gravel cover is largely masked by the greywacke conglomerate of the basement beds; but towards the eastern end deposits of marine gravel covering the cut platform show that it has been carved by the sea. This conclusion is strengthened by a detailed examination of its inner edge and a consideration of its extent, neither of which supports a hypothesis of river origin.

The terrace is not found south of Cape Kidnappers, and the most probable explanation of its presence in this locality is that it has been protected by its position along the side of Hawke's Bay from the erosive action of the sea, which has obliterated all traces of it on the coast south of the Cape.

CAPE KIDNAPPERS TO WAIMARAMA (16 miles).

Southward of Cape Kidnappers the rocks are typical Tertiary mudstones, marls, and sandstones, forming cliffs up to 400 feet high facing the sea. Near Cape Kidnappers a beach of boulders (up to 15 inches diameter) at present protects the cliffs from erosion by the sea, but two miles farther south a sand beach is in evidence, and continues almost unbroken to Waimarama. At three places, however, the remnants of former headlands, which existed before the bights or shallow bays between them were filled in with waste, break the continuity of the beach.

In many localities no true cliffs can be said to exist behind the sand beach, as immense landslides have taken place, leaving arcuate scarps above and piling up mounds of debris, mostly soft mudstone, on the rear portions of the beach, sometimes beyond, sometimes within reach of the waves. These landslides form a prominent feature of the coast from Cape Kidnappers as far almost as Castlepoint, and in some districts render the coastal route wellnigh impassable. This portion of the coast has recently undergone an uplift of 20 feet, and the waves no longer reach to the base of the cliffs which they had formerly cut, so that these immense slips cannot be attributed to normal marine undercutting. It seems most probable that they are the result of very recent earthquakes.

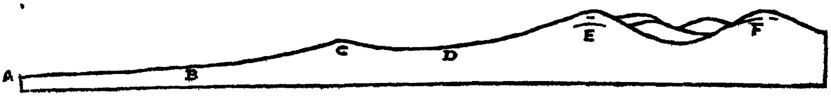

FIG 2.—Diagrammatic section across beach north of Haupouri.

A. Sea level.
B. Present beach.
C. Beach ridge of sand.
D. Depression or swale behind beach ridge.
E. and F. Lines of dunes.

In two localities north of Haupouri and at Waimarama the coast has prograded a short distance, and appears at present to be appreciably advancing seaward. The beach profile is composite (Fig. 2) as though another stage in the general seaward advance of the shoreline was nearly complete, the beach ridge being almost sufficiently high to form the base for another line of dunes when enough waste is available. The lower hinder portion of the beach will, if this occurs, form a marshy swale behind the youngest line of dunes. Just south of Haupouri small " 'tween tide " platforms cut in mudstone, similar to those described from the coast north of Castlepoint (King, 1930, p. 516; Pl. 80, Fig. 2) are present.

A little south of Cape Kidnappers remnants of a 20 feet marine bench have been recorded (Waghorn, 1927, p. 26). These are cut in rock 10 feet above high water mark, and are covered by 10 feet of poorly assorted gravel which has been only partly modified by marine agencies. Three-quarters of a mile south of Haupouri is a small terrace level at 10 feet, five feet of which consists of soft sandy cover; and two miles north of Waimarama the 20 feet terrace again shows, 12 feet being the thickness of the gravel cover at the seaward edge. All these terrace remnants may have been, and probably were, cut at the same time, slight differential uplift accounting for the observed differences in height.

A small local terrace attributable to stream-cutting alone is present at 250 feet behind Haupouri, and a somewhat similar terrace a mile to the south is probably of the same origin. Their accordance of level may imply a period of standstill, though no further evidence of such was obtained, unless these remnants be correlated with the Clifton to Cape Kidnappers marine bench.

WAIMARAMA TO BLACK HEAD (33 miles).

The axis of an anticline trending somewhat north of east passes through the country about two miles south of Waimarama. The rocks, chiefly sandstones, with a little mudstone and greensand, are of Cretaceous age and contain *Inoceramus, Pecten* sp., and a *Belemnite.* The sandstones frequently exhibit cone-in-cone and " cannon-ball " concretionary bodies. Southward, Lower Tertiary rocks flank the coast, the most prominent member being a coarse, impure, shelly limestone which, when struck with a hammer, smells slightly of oil. This thick limestone forms the bold escarpment, 900 feet high, which faces the sea from a point south of Waimarama to Mangaki, where its height has decreased to 500 feet. The rocks towards Poanui Point are mostly younger, though a small anticline just north of the point discloses a concretionary band similar to that overlying the limestone at Te Apiti. This may be the locality where Ongley collected an ammonite specimen (Marshall 1926, p. 132). From Poanui Point to Black Head the grain of the country runs parallel to the coast, so that the only rocks observed outcropping on the coastal section were mudstones of probable Tertiary age.

From Waimarama to Te Apiti the coastal route is impassable, though short lengths may be traversed. At the Te Apiti end, blocks of limestone from 8 feet to 10 feet across lie strewn at the foot of the cliffs (here 600 feet high) from which they have fallen, and form a surface over which travelling is very slow. The sea, however, still attacks the base of the cliffs at high water in some localities. Between Te Apiti and Mangaki the escarpment has in part collapsed, producing enormous landslides, the debris from which the sea is now actively engaged in removing.

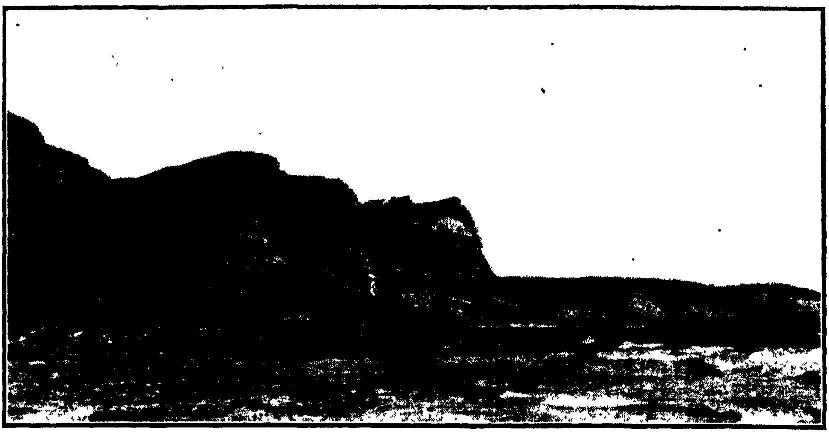

Fig. 1.—The coastal section west of Black Reef, Cape Kidnappers.

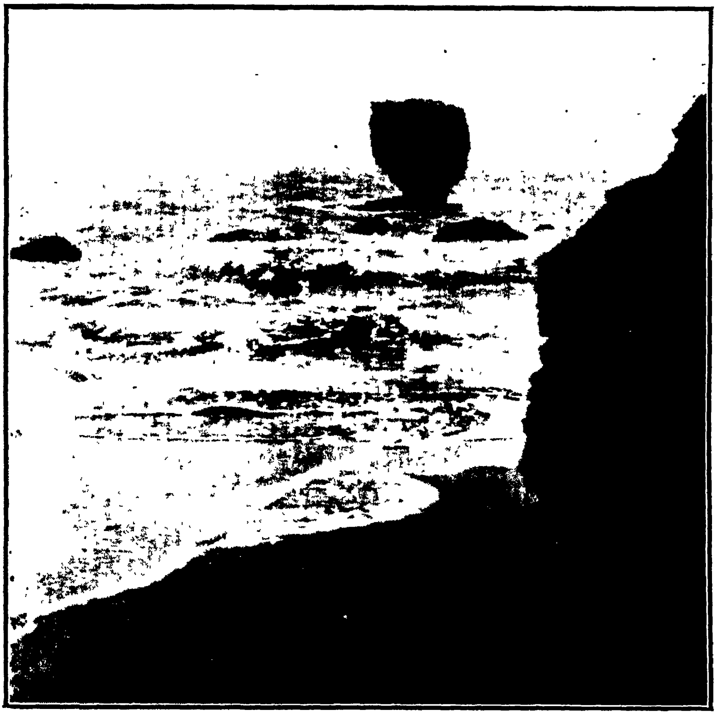

Fig. 2.—Stack undercut at high water mark, Black Reef, Cape Kidnappers.

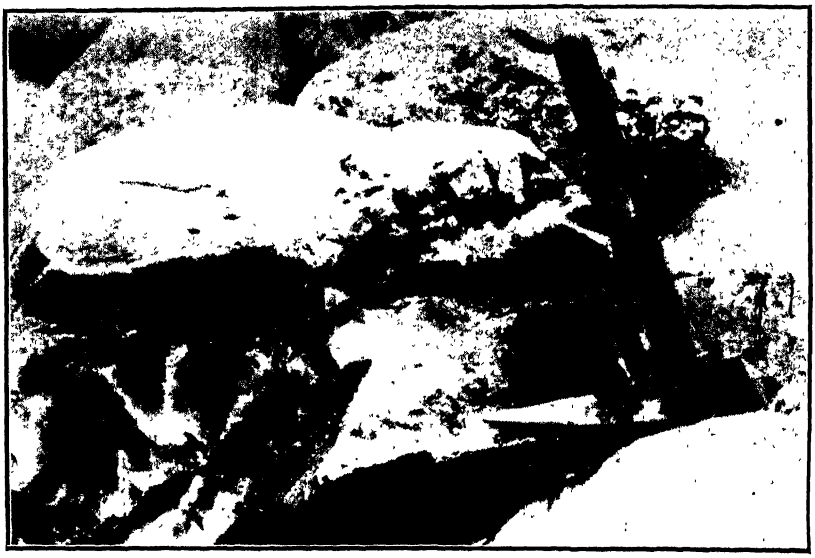

FIG. 1.—Concretionary body with transverse cracks, giving a resemblance to a vertebral column, Cape Kidnappers.

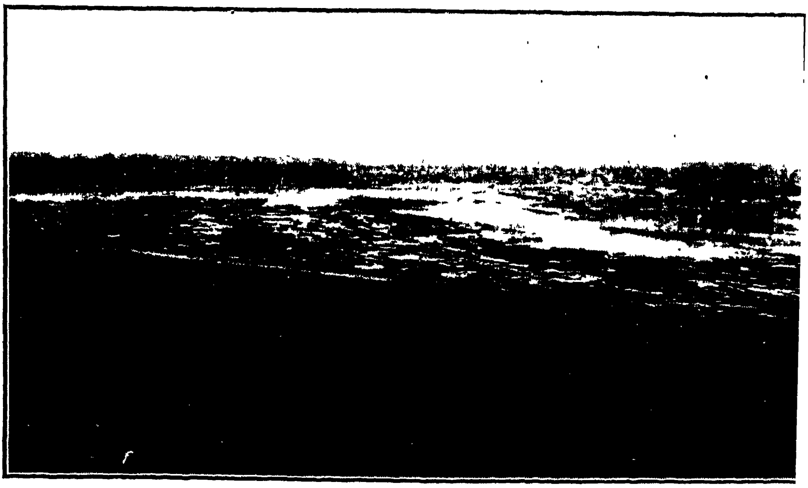

FIG. 2.—"'Tween tide" mudstone platforms, Poanui Point. Photograph tak at half tide.

Southward of Mangaki, stretches of beach are alternately sandy or bouldery, and about one mile north of Poanui Point spherical concretions up to four feet in diameter are strewn about the beach, being derived evidently from the rocks previously described. As at Te Apiti Station, these concretions frequently exhibit stratification planes passing through them, and are probably epigenetic in origin. A fine sand beach extends from this point to Poanui Point, where, seaward of the sand, extensive flat " 'tween tide " platforms of mudstone are well developed (Pl. 18, Fig 2). These platforms, which reach a width at Poanui Point of over 100 yards, are in every respect akin to those previously studied and described from Whakataki (King, 1930, p. 516). Owing to their almost horizontal surface the sea retreats and advances across them at a surprising speed just before and after low water. These platforms, which occur so noticeably in many of the localities described herein, appear to be a function of the rock in which they are cut. The same features have been noted at Cape Campbell, South Island, by Jobberns (1928, p. 515), who records that they can be traced along the coast for several miles. A feature of these soft Tertiary marls and mudstones is that, when damp, they prove very coherent, but upon drying they become friable and crumble away. Thus those portions which are below low water mark, or just sufficiently far above not to be dried by the sun and wind before the returning tide covers them again, remain solid, whereas those parts which are alternately wetted by the water and dried by the action of the sun and wind crumble, and are easily removed by the sea. They are thus largely analogous to the rock platforms described from the Bay of Islands by Bartrum (1916, p. 132).

From Poanui Point to within three miles of Black Head the shore consists of firm sand beach with a regular profile backed, near the headlands, by cliffs rising to a height of 400 feet. Seaward of the beach occur the " 'tween tide " platforms of mudstone, especially well developed on the headlands and diminishing or disappearing at the heads of small bays. A stretch of two miles north of Black Head has a coarse boulder beach instead of sand above the cut platform of mudstone.

BLACK HEAD TO PORANGAHAU (8 miles).

From Black Head to Porangahau the coastline is locally a coast of submergence which has been modified chiefly by the accumulation of waste under the influence of marine and alluvial agencies. After the drowning movement and the dismembering of the mature valley system in the lower reaches of the Porangahau River it seems that, under the influence of longshore currents, a spit grew across almost the whole of the open side of the depression, to enclose a large area of open water. At this stage it is likely that the gap in the spit through which the Porangahau River entered the sea was near the north end, towards Black Head. Smaller bays were then filled from their heads by streams flowing into them, and gradually almost all of the space behind the long spit was filled in.

Later, as the infilling at the north end of the lagoon progressed, the Porangahau River broached the spit at a point much farther south.

That the spit was flung across the shallow bay formed by the submergence at a very early stage, and that the sand beach is not merely the result of normal progradation is shown by the following features:—

(1) The boundaries of the depressed landscape show no signs of marine cliffing, and must have been early protected from wave-attack.

(2) Just landward of the beach is a marshy area extending parallel to the shore. This represents a partly infilled portion of the former lagoon, and in some parts probably marks the former extension of the Porangahau River.

(3) Along the first line of dunes behind the sea beach occur extensive Maori middens showing that, within very recent times at least, there has been no active progradation of the shore.

Much of the material of this area drifts in the form of dunes under the influence of winds, and has so modified the surface that it is somewhat difficult to obtain evidence of definite stages in the growth of the spit and the infilling of the lagoon. It certainly appears, however, that the spit (now broached near the centre by the Porangahau River) was built by marine action at approximately the present position of the shoreline, subsequent infilling by streams taking place behind this barrier; rather than that there was, at any time, an advance seaward of a completely filled-in feature.

PORANGAHAU TO CASTLEPOINT (53 miles).

The shore route was not followed from Porangahau to Herbertville, but from observations made at various points somewhat inland the coast appears to be very similar to that immediately north of Black Head (q.v.).

Raised terraces up to 50 feet near Herbertville have been recorded by Henderson (1915, p. 103; 1924, p. 584), but the writer was unable to locate any terrace higher than 10 feet above high tide mark. Between Herbertville and Speedy's a terrace form is present at about this height, but no evidence was obtained that it was of marine origin. The fact that the Wainui River turns east and flows along the rear portion of the beach to Tautane before breaking through to the sea may also suggest the formation of an offshore bar on a slightly emergent coast, turning the stream aside and later forming a beach, though normal longshore drift, similar to that at Porangahau, is also capable of forming such a feature.

From Herbertville to Aohanga the coast is very similar to that between Cape Kidnappers and Black Head, and need not be described in detail. Between Aohanga and Mataikona extensive low-angle fans of streamwash gravel extend from the base of the cliffs across a broad, almost plane, area to the sea. These are very similar to the outwash fans south of the Muka Muka, West Palliser Bay. South of these fans, sandy beach backed by high cliffs is present most of the way to Castlepoint.

CONCLUSION.

For the most part the coast herein described may be regarded as emergent coast which has attained to the mature stage. The only locality where subsidence has occurred is at Porangahau, where later accumulations of sand have since considerably simplified the shoreline. A most surprising feature is the absence, south of Cape Kidnappers, of high-level marine terraces; especially as these have been recorded from the coast to the north (McKay, 1887, p. 198; Henderson and Ongley, 1920, p. 23) and to the south (King, 1930, pp. 511-517). Unfortunately, few soundings have been made along this portion of the coast, and without some knowledge of the form of the sea floor it would seem unsafe, as yet, to theorise upon the absence of terraces in this locality.

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On the System and Stage Names applied to Subdivisions of the Tertiary Strata in New Zealand.

By R. S. ALLAN, M.Sc. (N.Z.), Ph.D. (Cantab.), F.G.S.,
National Research Scholar.

[*Read before the Otago Institute, 17th June, 1930; received by the Editor, 6th November, 1931; issued separately, 28th February, 1933.*]

CONTENTS.

I.—INTRODUCTION.
II.—REVISION OF SYSTEM AND STAGE NAMES, IN ALPHABETICAL ORDER.
III.—SUMMARY OF CLASSIFICATION.
IV.—SOME GENERAL CONSIDERATIONS.
V.—LITERATURE.

I.—INTRODUCTION.

THE nomenclature in use in the Dominion for the major subdivisions of the Tertiary rocks is an extension of the scheme proposed by J. Allan Thomson in 1916. Marshall's alternative classification (1916, 1919), based upon the percentage of Recent species, has not been adopted by subsequent workers. As well as the system and stage names of Thomson's classification there are a host of series names which are of local value only. The latter are not further considered here.

There is now a general consensus of opinion among those studying Tertiary problems that Thomson's scheme is not sufficiently detailed. Of this fact Thomson himself was fully aware. He wrote: "With the detailed palaeontological work on Tertiary Mollusca now being carried out by Marwick, Finlay, and others it is becoming evident that the stages of the Oamaruian as originally proposed by me (1916) are not, as was at first thought by other geologists, too numerous and small in content for classificatory purposes, but the reverse. Important faunas, such as that of Otiake and those of Clifden, while undoubtedly Oamaruian, do not appear to agree exactly with any of the stages in the Oamaru coastal district, and probably represent stages missing between Ototaran and Hutchinsonian, or between Hutchinsonian and Awamoan. If this is so there must be important unconformities or disconformities between these stages in Oamaru." (1926, p. 145.)

However, before introducing any new terms, it seems advisable to summarise what has already been done. Stage names have been introduced without adequate definition by more than one worker, and these should be carefully scrutinised, and, if necessary, defined accurately or else rejected.

It is well to bear in mind that a scheme of classification is but a means to an end. The various stage-names are primarily tools for the convenience of the stratigrapher. It is obvious that the better the tool the better will be the use of it in skilled hands.

The economic geologist and stratigraphical palaeontologist both demand that their units shall be accurately and clearly defined. Recent work in the British Isles has demonstrated very clearly that stratigraphy can be a very exact science.*

When the palaeontologist is able to study fossils which have been collected from well-defined units he is able, more often than not, to provide the stratigrapher with very accurate information as to age or correlation of the strata in question. The stratigrapher gains from his exact work. This is nowhere more apparent than in recent developments in oil-geology, and has a great economic significance.

It seems to the writer that the stage-names in New Zealand are imperfectly defined, with the result that, in spite of the palaeontological data now available, exact correlation is practically impossible in many cases.

Too much attention has been paid to individual fossils, their description, and the determination of their range in time. The tendency of modern palaeontology is towards (a) the study of restricted groups of organisms as they develop in time; and (b) the study of faunal communities or assemblages rather than of individuals.

Neither of these methods has yet been applied in the Dominion. The first means more than merely recording the succession of different forms in time. The object is to find the stratigraphical value of stages in development in particular lineages. The guiding principle is that stages of development in any one lineage are successive in time. This science of stratigraphical palaeontology demands of its devotees a greater knowledge of fossils in the field than do the older methods. The focus of modern work is in the field rather than in the museum. The significant changes in many lineages are so intimately related to changes in lithology or facies that they can only be appreciated fully in the field.

In a report on the Lower Devonian fossils of Reefton, soon to be published, the writer has attempted to show the value for purposes of correlation of faunal communities based upon characteristic fossils. It is not necessary, therefore, to provide full details of this type of study here. It will be sufficient to state that a given horizon of uniform facies can be treated in terms of its characteristic fossils alone. For practical purposes a characteristic fossil of a given horizon and facies is one which is there abundant. It is not necessary to know the complete fauna, nor is it vital to determine the exact range of any individual species.

Fossil communities, in the same way as recent animal and plant communities, are bounded by certain physical conditions, and are constant only where the physical conditions are constant. A change in environment results in a change in the community as far as the characteristic members of it are concerned.

---

* See for example W. D. Lang (and others). The Belemnite Marls of Charmouth, a Series in the Lias of the Dorset Coast. *Quart. Jour. Geol. Soc.* LXXXIV (2), 1928, pp. 179 *et seq.*

It is thus of great importance to realise that a community characteristic of a certain stage in the type locality will be characteristic of that stage only in areas where it is represented by strata of the same facies.

I would submit, therefore, that before correlation of faunas of distinct facies is possible one must understand clearly the characteristic fauna in its relation to the facies of the type area.

In very few cases is it possible in the Dominion to enumerate standard characteristic communities. This is because in most cases the type localities for our stages are not fixed, or because the fossils from type localities are imperfectly known. Until these deficiencies are made good it is impossible, in the writer's opinion, to expect to get any accurate data as a basis for sound correlation.

Before either of these methods, viz., the study of restricted groups of organisms as they develop in time, and the study of faunal communities based upon characteristic fossils, can be applied in New Zealand there must be a more rigorous definition of stratigraphical units. This is attempted in the sequel.

For each stage I propose to select a definite type locality which will form a standard for that stage. Each stage will be based upon definite lithological units which will be defined as accurately as possible. When they are known the most characteristic fossils will be listed. Stress will be laid upon the community rather than upon the individual.

In selecting type or standard localities the clearness of the section and the state of preservation of the fossils will receive consideration, but underlying the selection the law of the superposition of strata will be the guiding factor as far as it is applicable in any one area.

I should like to suggest that if the stages herein employed prove to contain more than one community in sequence in the standard area, then each might fittingly be spoken of as a zone. Each zone would be indicated by selecting an index-fossil, thus the "Zone of *Stethothyris sufflata*"; or, more simply, the *sufflata*-zone.

It is therefore possible, in some cases certain, that the stages will be subdivided into zones. This method is more convenient than the excessive introduction of stage or substage names. For gaps between the stages as herein defined, however, new stages will be both necessary and desirable. Such a scheme should make for permanence of nomenclature—a most excellent aim.

It appears to the writer that the first task of Dominion students is not to attempt correlation problems, but to study in detail the faunas of the standard areas. Only after these are thoroughly known in relation to their particular facies can correlation be attempted. Areas other than standards could well await study until knowledge of the standards is reasonably complete.

A second task concerns the study of changes in faunal assemblages in relation to changes in facies. This can only be attempted by palaeontological studies in the field after the standard faunas and facies are determined.

It will be obvious that the writer owes a great deal to the worthy pioneers of Tertiary stratigraphy in New Zealand, A. McKay, F. W. Hutton, James Park, and P. Marshall, but his indebtedness to the younger workers, J. Allan Thomson, G. H. Uttley, J. Marwick, L. I. Grange, H. J. Finlay, and others, will be equally apparent.

Dr J. Marwick* and Dr H. J. Finlay have both offered most helpful criticism of my manuscript. The latter's help in connection with lists of characteristic mollusca has been invaluable.

II.—REVISION OF SYSTEM AND STAGE NAMES.

The following names have been used for subdivisions of the Tertiary strata of New Zealand:—Atiuian, Awamoan, Awaterian, Bortonian, Brunnerian, Castlecliffian, Hutchinsonian, Islandian, Kaiatan, Kaitangatan, Mawheranuian, Ngaparan, Nukumaruian, Oamaruian, Onairoan, Ototaran, Paparoan, Pareoran, Petanian, Tahuian, Taranakian, Tongaporutuan, Urenuian, Waiarekan, Waimangaroan, Waimateian, Waipipian, Waitakian, Waitotaran, Wangaloan, and Wanganuian.

Of these the following are system or group names:—Kaitangatan, Mawheranuian, Oamaruian, Taranakian, Waimangaroan, and Wanganuian.

ATIUAN Stage.

Proposed by P. G. Morgan (1921, p. 101 and p. 103).

The name appears first in "Table I—Classification of Cretaceous and Tertiary Strata" and there covers (a) Part of Kaeo Series; hydraulic limestone (Northern Auckland); (b) Mangatu Series (East Coast of North Island); and (c) Amuri limestone (Marlborough and North Canterbury). In the "Remarks on Classification Table" Morgan wrote: "The adjective 'Atiuan' [final 'i' omitted] from Atiu Point, Kaikoura Peninsula, is intended to cover the Amuri limestone, for which a stage or alternative name, notwithstanding its poverty in fossils, seems desirable." (1921, p. 103.)

The fossils of the Amuri limestone are chiefly foraminifera, and F. Chapman (1926, pp. 10-11) has concluded that these organisms indicate a Danian (Upper Cretaceous) age. If this age be accepted the Atiuian need not be considered further in the classification of the Tertiary sequence.

Thomson's suggestion (1916) that the Amuri limestone is Cretaceous at the base but Tertiary at the top is not borne out by Chapman's studies of the foraminifera. (See Thomson, 1920, pp. 385-6.)

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* Since these notes were written Dr Marwick has published *(N.Z. Geol. Surv. Pal. Bull.* No. 13, 1931) a "Synopsis of the Commonly Used Stage Names of the New Zealand Tertiary." This synopsis is referred to where necessary in footnotes in the sequel.

AWAMOAN.

Proposed by J. A. Thomson (1916, p. 34) for the "Awamoa Beds" of the Oamaru district.

The name is based upon Awamoa Creek, but no type locality was cited by Thomson. The strata exposed at the mouth of Awamoa Creek are isolated from all other rocks of Oamaruian age (Park, 1918, p. 87); hence this area is not suitable for a standard. However, one wing of the syncline here developed is clearly exposed at the Rifle Butts, and there is available there a clear measured section (Park, 1918, pl. IV) which is here selected as the type locality of the Awamoan stage. Park gives the following sequence (in descending order):—

(a.) Blue sandy clays; 30 feet exposed.
(b.) Band of hard calcareous sandstone; 18 inches.
(c.) Blue sandy clays; 8 feet.
(d.) Band of hard calcareous sandstone; 16 inches.
(e.) Blue sandy clays; 43 feet.
(f.) Hard calcareous band; 18 inches.
(g.) Soft glauconitic sands; 9 feet.
(h.) Hard brown limonitic sandstone; 2 feet.
(i.) Glauconitic sandy shell-bed; 5 feet.
(j.) Greensands with *Pachymagas parki;* 5 feet.

Park placed beds (a.)-(f.) in the Awamoan; beds (g.) to (j.) (and certain lower horizons) in the Hutchinsonian. With regard to horizon (j.) there can be no dispute—it is definitely Hutchinsonian, but G. H. Uttley (1920 B, pp. 173-4) has argued, correctly, that bed (i.) is the equivalent of the shell-beds of Target Gully and Ardgowan which Park admits are basal Awamoan.

The Awamoan stage may be defined as the interval of time represented by the deposition of beds (a.) to (i.) in the standard section at the Rifle Butts, Oamaru, and as well such periods as may be represented therein by non-deposition or erosion. Two faunal communities may be recognised in the Awamoan period. The first is basal Awamoan, and is found in the shell-bed of the Rifle Butts, Target Gully, Ardgowan, etc. This faunule is best known at Target Gully, and a list of the characteristic mollusca found there by Dr H. J. Finlay is given below. The second faunule occurs in the blue clays of the Rifle Butts, Awamoa Creek, Pukeuri, All Day Bay, etc. As typical I list the characteristic mollusca from the type locality at the Rifle Butts.

The characteristic mollusca of the Target Gully shell-bed are:—*Acteon praecursorius* Suter, *Alcithoe compressa* Marw., *A. cylindrica* Marwick, *A. finlayi* Marwick, *Alocospira hebera* (Hutton), *Anomia trigonopsis* Hutton, *Argalista impervia* Finlay, *Ataxocerithium pyramidale* Finlay, *Austrodrillia callimorpha* (Suter), *Austrofusus spinifera* (Finlay and McDowall), *Austrotoma minor* Finlay, *Austrotriton maorium* Finlay, *Barbatia awamoana* Finlay, *Bullinella soror* (Suter), *Chathamina compacta* (Suter), *Cochlis notocenica* (Finlay), *Comitas oamarutica* (Suter), *Corbula pumila* Hutton, *Cryptomella excavata* (Hutton), *Cucullaea australis* (Hutton), *Cymatiella octoserratum* (Finlay), *Dosinia (Raina) bensoni* Marwick, *Dosinula suboblonga* Marwick, *Egestas fenestrata* (Suter), *Eucominia intermedia* (Suter), *Eucrassatella attenuata* (Hutt.), *Eumarcia (Atamarcia) curta* (Hutton), *E. (A.) sulcifera* Marw., *Fissidentalium solidum* (Hutton), *Gari oamarutica* Finlay, *Glycymeris robusta* Marw., *Hima socialis* (Hutt.), *Hinnites trailli* Hutt., *Kuia vellicata* (Hutt.), *Limopsis zitteli* von Ihering, *Maoricolpus cavershamensis* (Harris), *Maoricrypta radiata* (Hutt.), *Maorivetia brevirostrus* (Hutt.), *Marginella conica* Harris, *M. harrisi* Cossm., *Mesalia striolata* (Hutt.), *Miopila fidicula* (Suter), *Monia incisura* (Hutt.), *Nassicola contracta* Finlay, *Navicula subvelata* (Suter), *Notocallista parki* Marwick, *Notacirsa oamarutica* (Suter), *Nucula sagittata* Suter, *Oamaruia suteri* (M. & M.), *Pachymelon firma* Marwick, *Pallium (Mesopeplum) burnetti* (Zittel), *Panope worthingtoni* (Hutt.), *Parasyrinx alta* (Harris), *Parvimitra scopi* Finlay, *Polinices huttoni* von Ihering, *P. lobatus* Marwick, *Procominula pukeuriensis* Finlay, *Proximitra rutidolomum* (Suter), *Pteronotus awamoanus* Finlay, *Rhizorus reflexus* (Hutt.), *Rugobela canaliculata* (Suter), *R. tenuilirata* (Suter), *Sigapatella maccoyi* Suter, "*Siphonalia*" *excelsa* Suter, *Spinomelon parki* (Suter), *Spissatella scopalveus* Finlay, *Struthiolaria subspinosa* Marw., *Tawera marshalli* Marwick, *Teredo heaphyi* Zittel, *Teremelon cognata* (Finlay), *Trichomya huttoni* (Cossm.), *Uromitra etremoides* Finlay, *Venericardia awamoaensis* (Harris), *Verconella marwicki* (Finlay), *Waimatea othoniana* (Finlay), *Xymenella lepida* (Suter), *X. minutissima* (Suter), *Zaclys aequicincta* (Suter), *Zeacolpus abscisus* (Suter), *Zeacrypta wilckensi* (Finlay), *Zeacuminia pareoraensis* (Suter), *Zeapollia acuticingulata* (Suter), and *Zenatia acinaces* Q. and G.

The characteristic mollusca in the blue clays at the Rifle Butts include:—*Alcithoe neglecta* Marwick, *Alocospira hebera* (Hutt.), *Austrodrillia praecophinodes* (Suter), *Austrotriton maorium* Finlay, *Bullinella soror* (Suter), *Chathamina protensa* (Powell), *Cochlis notocenica* (Finlay), *Coluzea dentata* (Hutt.), *Comitas oamarutica* (Suter), *Egestas fenestrata* (Suter), *Friginatica vaughani* (Marwick), *Hima socialis* (Hutt.), *Lima colorata* Hutt., *Limopsis zelandica* Hutton, *Marginella conica* Harris, *M. fraudulenta* Suter, *M. harrisi* Cossm., *Neilo awamoana* Finlay, *Parasyrinx alta* (Harris), *Parvimitra pukeuriensis* Finlay, *Procominula pukeuriensis* Finlay, *Proximitra apicale* (Hutt.), *P. tumens* Finlay, *Rugobela canaliculata* (Suter), *Spissatella trailli* (Hutt.), *Teremelon awamoanensis* Marw., *Uberella pseudovitrea* (Finlay), *Venericardia awamoaensis* (Harris), *Vesanula vegrandis* (M. & M.) and *Zeadmete miocenica* Finlay.

AWATERIAN.

Proposed by P. G. Morgan (1922, p. 52).

"In some parts of New Zealand there occur strata known by their stratigraphical position and molluscan fauna to be somewhat younger than the typical Awamoan, but not easily separable either from it or from the strata forming the lower part of the Wanganuian. These are the Awatere beds, and form what may perhaps be called the Awaterian stage, which, however, is at present not clearly definable, and must simply be considered as intermediate between Awamoan and Wanganuian. In this category come not only certain strata in the Lower Awatere Valley, but portions of the strata in southern and central Taranaki that comformably underlie undoubted Wanganuian, together with the Ormond limestone and Tawhiti beds of the Gisborne district."

It is still impossible to define Morgan's term, and it should be allowed to lapse. The time interval between the Oamaruian and the Wanganuian is bridged by the Taranakian System of L. I. Grange.

The terms "Awaterian" and "Taranakian" are in part or completely synonymous, but there is nothing to be gained by the rejection of the latter on grounds of priority.

BORTONIAN.

Proposed by J. Park (1918, p. 25) as the lower substage of the Waiarekan as originally used by Thomson (1916).

Type locality: Near Borton's, in the Waitaki Valley, 24 miles from Oamaru.

Park (1918, pp. 33-4) gives the following sequence of strata in the type locality (in descending order) :—

(a.) A yellowish-brown calcareous sandstone.
(b.) Glauconitic greensands; 5 feet.
(c.) Greyish sandy beds; 10 feet.
(d.) Brown sandy beds, slightly glauconitic; 130 feet.
(e.) Soft brown sandstone, interbedded with a band of hard calcareous glauconitic sandstone, 6 inches to 2 feet, 30 feet in thickness.
(f.) Coal-measures.

The Bortonian fossils occur in the hard band in horizon (e.). Allan (1927, pp. 284-90) has suggested that since the fossils at Borton's are poorly preserved, a palaeontological basis may be given the Bortonian by reference to the sequence developed in the Lower Waihao Valley. In this locality Bortonian fossils are beautifully preserved, and the relationship of the Bortonian fauna to overlying faunas is clear.

Allan gave the following sequence (in descending order) :—

(a.) Waihao limestone	Ototaran	
		(disconformity)
(b.) Upper greensands	Tahuian	Waimateian.
	(diastem)[*]	
(c.) Lower greensands (d.) Hard sandstones	Bortonian	
And		
(e.) Coal-measures.		

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[*] According to Willis and Willis *Geologic Structures* (1929), a conformable contact between strata which are not separated by a notable time break is called a diastem. A conformable contact which is characterised by a notable lapse of time is called a disconformity.

If this suggestion be allowed, *the Bortonian Stage may be defined as the interval of time represented by the deposition of the lower greensands and sandstones in the Lower Waihao Valley, and as well such periods as may be represented therein by non-deposition or erosion.*

The top of the lower greensands is marked by a phosphatised surface at McCullough's Bridge.

The characteristic mollusca of the Bortonian, based upon personal observation, are:—*Carinacca allani* Marwick, *Cucullaea waihaoensis* Allan, *Friginatica prisca* (Marwick), *Fusinus bensoni* Allan, *Globisinum elegans* (Suter), *Insolentia sertula* (Suter), *Latirus neozelanica* (Suter), *Limopsis campa* Allan, *Marshallena serotina* (Suter), *Mauia curvispina* Marwick, *Monalaria concinna* (Suter), *Notoplejona necopinata* (Suter), *Pecten devinctus* Suter, *P. waihaoensis* Suter, *Speightia spinosa* (Suter), and *Venericardia acanthodes* (Suter).

BRUNNERIAN Stage. See Mawheranuian System.

CASTLECLIFFIAN Stage. See Wanganuian System.

HUTCHINSONIAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-5) for the " Hutchinson Quarry Beds " of the Oamaru Coastal District. " In the Hutchinsonian I would place all beds between the Ototaran limestone and the shell-bed at Target Gully, described by Marshall and Uttley (1913), the latter forming the base of the Awamoan." (Thomson, 1916, p. 35.)

The name is used by Thomson for a lithological unit, and a type locality, although not definitely stated, is implied in the name. Unfortunately the sequence of strata developed at and near Hutchinson's Quarry is somewhat obscure. Thomson's base line, the top of the Ototaran limestone, can be distinguished at the Quarry only with difficulty. Furthermore there is no clear contact in Target Gully between the greensands of Hutchinson's Quarry and the basal Awamoan shell-bed which is itself probably a very local deposit.

In fact Park (1918) has recognised fossiliferous strata between the greensands and the Awamoan shell-bed at Target Gully itself. This horizon, which has a moderately rich, well-preserved, molluscan fauna, was ignored by Thomson, and has been neglected by all subsequent workers.

If therefore the Hutchinsonian be interpreted by the sequence in Lower Target Gully, it contains three lithological units, each characterised by a distinct fauna:—

(a.) Glauconitic sands with mollusca and *Tegulorhynchia*—" Upper Hutchinsonian " of Park (1918).
(b.) Greensands with *Pachymagus parki.*
(c.) Phosphatic conglomerate with *Liothyrella boehmi.*

If, on the other hand, a standard locality be selected elsewhere in the Oamaru District, a further difficulty presents itself. The greensands of the Rifle Butts, Kakanui, Devil's Bridge, All Day Bay, and Deborah, i.e., correlatives according to Thomson and earlier workers, of the Hutchinson's Quarry Beds, contain a brachiopod assemblage distinct from that of Hutchinson's Quarry. In other words, the lithic boundary of the greensands appear to cut across the true time planes. The brachiopod evidence for this view is detailed by Thomson (1926, p. 150.)

It would seem to be obvious that a precise definition of the Hutchinsonian stage must await the detailed stratigraphical and faunal studies required to clear up the obscurity implied in the above statements.

In the meantime the Hutchinsonian may be defined as the period of time during which the Pachymagas parki *series of brachiopods were the characteristic fossils.*

As thus interpreted the Hutchinsonian includes, as well as the strata noted in Target Gully, the greensands of the Oamaru Coastal District (Rifle Butts, Deborah, etc.); the main Mount Brown limestone; the limestones of Winton and Clifden in Southland; and the greensands of the Curiosity Shop, Rakaia River.

From the faunal point of view more detailed subdivision is possible. The following faunules may be differentiated:—

(a.) A brachiopod faunule characteristic of the basal phosphatic horizon in the Oamaru Coastal District. (See Thomson, 1926, p. 150, Table I.) At this horizon *Mopsea hamiltoni* (Thomson) and *Isis dactyla* Tenison-Woods are also noteworthy.

(b.) The *Pachymagas parki* assemblage. Found in the greensands of Hutchinson's Quarry; in the main Mount Brown limestone, Weka Pass; and in the Clifden limestone. Characteristic brachiopods are *Pachymagas parki* (Hutton), *Rhizothyris rhizoida* (Hutt.), *R. scutum* Thomson, *R. elliptica* Thomson, *Waiparia intermedia* Thomson, and *Magadina browni* Thomson.

(c.) The *Pachymagas hectori* assemblage. This is restricted to the greensands of Deborah, the Rifle Butts, Devil's Bridge, etc., in the Oamaru Coastal District.
And

(d.) A molluscan faunule known only from Park's Upper Hutchinsonian of Target Gully. This faunule has not been critically examined.

Park (1918, p. 25) proposed the term Waitakian as an upper substage of the Hutchinsonian. This proposal is discussed in the sequel.

P. G. Morgan (1921, p. 103) suggested that the Hutchinsonian should be merged into the Ototaran; and (1922, p. 52) that it should be included in the Awamoan stage. Neither suggestion warrants serious consideration.

ISLANDIAN Stage. See Mawheranuian System.

KAIATAN Stage. See Mawheranuian System.

KAITANGATAN System or Group.

Proposed by J. A. Thomson (1917, pp. 410-11) for " the Kaitangata upper and lower coal-measures as described by Park (1911) and the intermediate marine horizon, but excludes the Oamaruian coal series and overlying Oamaruian marine rocks which rest unconformably, according to Park, on the Kaitangata coal-measures proper." (1917, p. 410.)

Recent work by M. Ongley (1926) would seem to show that the Kaitangatan of Thomson contains both Tertiary and Cretaceous rock units. Ongley shows that the Kaitangata coal-measures (stated to be of Upper Cretaceous age) are separated from the overlying Taratu coal-measures which include sandstones with marine fossils—the Wangaloa beds—by " a period of elevation, accompanied by tilting or folding and probably by faulting." (1926, p. 83.) These facts made it doubtful whether Thomson's system name should be retained. The matter may perhaps be left until after the publication of the Survey Bulletin dealing with this area. The only marine stage of the Kaitangatan is the Wangaloan, and this will be discussed in the sequel.

MAWHERANUIAN.

Proposed by P. G. Morgan (1918, p. 40; 1922, p. 52) as a group or system name to include strata developed typically in the Greymouth subdivision of North Westland.

Morgan (1911) gave the following sequence (in descending order:—

(a.) Kaiata Mudstone.		2000-3000 feet
(b.) Island Sandstone.		500 feet
(c.) Brunner Beds	i. Coarse sandstones, grits, and pebble-beds.	300-400 feet
	ii. Pebble-beds and conglomerates.	0-400 feet
(d.) Paparoa Beds	i. Upper sandstones and shales.	700-800 feet
	ii. Middle sandstones with minor shales.	500-600 feet
	iii. Lower sandstones and shales.	700-800 feet
	iv. Basal conglomerates with minor sandstones.	0-1000 feet

The coal-measures thus defined are the exact equivalent of Park's " Waimangaroa Series " (1910, pp. 101-7). Morgan (1922, p. 52) therefore proposed Waimangaroan or Mawheranuian. The two terms are exactly equivalent, and since one term only is necessary I select Mawheranuian for the reasons given by Morgan (1911, pp. 53-4). The Mawheranuian may be defined as the period of time represented by the deposition of the Paparoa, Brunner, Island sandstone, and Kaiata beds, together with such periods as may be represented therein by non-deposition or erosion.

Thomson (1916, p. 39), based the non-marine Paparoan Stage on the Paparoa Beds as defined by Morgan. The same author considered that Morgan's conclusion that the Mawheranuian as a whole was older than the Oamaruian, was not justified on palaeontological data, and, therefore, did not base stage names on the Kaiata mudstone, the Island sandstone, or the Brunner beds.

Morgan (1918, p. 40; and 1922, table I, p. 56), however, proposed the Kaiatan, Islandian, and Brunnerian stages for the horizons in question, and regarded the whole of the Mawheranuian as Eocene. The Brunnerian is a non-marine stage, but the Kaiatan and Islandian contain marine fossils which are never abundant.

It is still impossible to define these stages palaeontologically. Hence it is impossible to state that the Mawheranuian System is distinct from the Oamaruian System. It is probable that they are in part at least equivalent.

As regards the Kaiatan and Islandian marine stages it is impossible yet to determine their relationship to the lower stages of the Oamaruian System, viz., Waiarekan, Tahuian, and Bortonian* or to the Wangaloan marine stage of the Kaitangatan System.

In any scheme for the division of Tertiary marine succession in the Dominion, it would seem wisest to omit the Mawheranuian System from consideration until such time as its faunal succession is better understood.

It should also be pointed out that the group name Kaitangatan proposed by Thomson (1917, p. 410) is probably the equivalent of at least part of the Mawheranuian of Morgan, and should take priority.

NGAPARAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-5) for the coal-measures at the base of Oamaruian of the Oamaru District. Thomson suggested " that ' Ngaparan ' should be restricted to coal-beds, and that a different stage name should be used for the normal marine beds of the same horizon." (1916, p. 35.) This stage name is not further considered in this summary.

NUKUMARUIAN Stage. See Wanganuian System.

OAMARUIAN System.

Proposed by J. Park (1910, pp. 108 et seq.), and used as the equivalent of his " Oamaru Series." The term was given its exact definition by J. A. Thomson (1916, p. 31), who employed it for " the whole Tertiary succession as developed at Oamaru, and its correlatives elsewhere."

As thus defined the Oamaruian includes the Ngaparan coal-measures. The writer prefers to omit this stage because it will be impossible to correlate any marine fossiliferous unit with it. It seems advisable to limit the Oamaruian by reference to marine strata.

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* J. Henderson (1929, p. 284) stated, on the authority of J. Marwick, that the Island sandstone at Ten Mile Bluff contains Bortonian fossils.

The Oamaruian may be defined as the interval of time which commenced at the beginning of the Bortonian period and ended at the close of the Awamoan period. The stages so far recognised in the Oamaruian are, in descending order, Awamoan, Hutchinsonian, Waitakian, Ototaran, Waiarekan, Tahuian, and Bortonian.

ONAIROAN Stage. See Taranakian System.

OTOTARAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-5) for the Ototara limestone of the Oamaru District.

Type locality: The selection of a standard area for the Ototaran presents difficulties because the sequence of strata forming this stage has been variously interpreted by different authorities. The Ototaran contains several faunal communities, some definitely in sequence; others possibly facies variants. These are as yet imperfectly understood.

I believe that if one locality were selected as a standard, impetus would be given to the necessary research, and the problem would be considerably clarified. As a working hypothesis I suggest that the type locality for the Ototaran Stage be along the line of section exposed from Trig. V., near Totara, east through Flat Top Hill to Deborah Road.

J. Park (1918, map opposite p. 66) has provided a section along this line.

The sequence (in descending order) is:—

1. Greensands with *Pachymagas* of the *parki* series.

Disconformity.

2. Deborah (or Kakanui) limestone.
3. Deborah tuffs.
4. Oamaru stone.
5. Waiareka tuffs.

The Ototaran may be defined as the period of time represented by the deposition of beds 2 to 4 in the above sequence, and as well such intervals as are represented therein by non-deposition or erosion.

It is at present impossible to cite the characteristic fossils of the Ototaran Stage except in a very general way.

Thomson (1926, p. 152) reported that "at least four more or less distinct brachiopod faunas are found in the Ototaran of the Oamaru coastal district, of which three in the Kakanui neighbourhood are clearly in sequence, viz., those of (1) the calcareous tuffs of Trig. M. and the limestone of Fortification Hill; (2) the Kakanui tuffs; and (3) the limestones of Kakanui and Flat Top Hill (Deborah limestone of Park)." These three divisions apparently correspond to those noted in the type locality.

The brachiopod faunules have not been studied in detail.

The upper—that of the Kakanui or Deborah limestone—contains an abundance of *Liothyrella oamarutica* (Boehm), *Terebratulina oamarutica* Boehm, and *Tegulorhynchia depressa* Th., and *T. sublaevis* Thomson.

The second horizon at Everett's Quarry is the type locality for *Liothyrella boehmi* Thomson. While from the lowest member, the calcareous tuffs, Trig. M., Thomson described *Liothyrella pulchra* Th., and *Terebratella totaraensis* Thomson, both species being abundant.

A fourth brachiopod community—termed by Thomson the *Liothyrella landonensis* fauna—has a wide occurrence wherever the Ototaran presents a glauconitic facies, e.g., at Landon Creek, in the Lower Waihao Valley, etc. Thomson correlated the strata containing this fauna with Kakanui limestone.

The *landonensis* fauna includes *Liothyrella landonensis* Th., *Tegulorhynchia depressa* Th., *Murravia catinuliformis* (Tate), *Terebratulina suessi* (Hutton), *Stethothyris tapirina* (Hutton), and other species enumerated by Thomson (1926, Table II, p. 152).

The lists in Park's Bulletin (1918) show clearly that the Ototaran tufaceous horizons yield a moderately rich molluscan fauna. A revision of this material is very necessary to a complete understanding of the Ototaran period.

PAPAROAN Stage. See Mawheranuian System.

PAREORAN Stage.

Proposed by P. G. Morgan (1918, 1921) as a substitute for the Awamoan Stage of Thomson. The latter was particularly chosen so that " all ambiguity caused by the use of the terms " Pareora series," " Pareora fauna," etc., may be avoided . . ." (Thomson, 1916, p. 34). Morgan's suggestion, therefore, has nothing in its favour.

PETANIAN Stage.

Proposed by P. G. Morgan (1918, p. 40) for the " Petane beds," and placed between the Castlecliffian and Waitotaran. Later, Morgan (1921, pp. 98 and 101) used this term as the equivalent of the Castlecliffian. The Petane beds of Hawke's Bay are Nukumaruian. It is therefore possible to argue that Petanian should replace Nukumaruian.

In the writer's opinion Petanian should be dismissed; it is clearly desirable that the type localities for the divisions of the Wanganuian should be selected from units on the Wanganui Coast.

TAHUIAN Stage.

Proposed by R. S. Allan (1926, 1927) as the upper substage of the Waimateian Stage. It has been granted the rank of a full stage by Marwick (1927).

Type locality: McCullough's Bridge, Lower Waihao River, South Canterbury.

The sequence (in descending order) is:—

1. Waihao limestone.

Disconformity.

2. Upper greensands, 20 feet.

Diastem.

3. Lower greensands, with the upper surface phosphatised.

The Tahuian may be defined as the interval of time represented by the deposition of the upper greensand at McCullough's Bridge, and as well such periods as are represented therein by non-deposition or erosion.

The characteristic mollusca collected by Dr Finlay and the writer are:—*Baryspira morgani* (Allan), *Borsonia rudis* (Hutt.), *Carinacca haasti* Marwick, *C. waihaoensis* (Suter), *Friginatica suturalis* (Hutton), *Gemmula bimarginata* (Suter), *G. complicata* (Suter), *G. waihaoensis* Finlay, *Limopsis waihaoensis* Allan, *Marshallena formosa* (Allan), *M. neozelanica* (Suter), *Nuculana semiteres* (Hutton), *Parvimitra plicatellum* (M. & M.), *P. subplicatellum* Finlay, *Spirocolpus waihaoensis* (Marwick), *Waihaoia allani* Marwick, *Waimatea inconspicua* (Hutt.), *Zeacuminia tahuica* Finlay, and *Zexilia waihaoensis* (Suter).

TARANAKIAN.

Proposed by L. I. Grange (1926, p. 334) as a group name for the period between the Wanganuian and Oamaruian Systems; also as a stage name to include the Onairo beds and the Tongaporutu beds of Taranaki.

It should be noted first that P. G. Morgan had earlier proposed the term Awaterian for strata intermediate between the Wanganuian and the Awamoan, and this term covered " portions of the strata in southern and central Taranaki that conformably underlie undoubted Wanganuian . . ." (1922, p. 52.) Grange does not mention his chief's work, but the two terms are clearly synonymous. However, the strata deposited in the interval between the Wanganuian and the Oamaruian are very fully developed in Taranaki, whereas the sequence in the Awatere Valley is very incompletely known. For this reason the Taranakian is clearly a preferable term, and Morgan's Awaterian Stage should be dismissed.

One must question the wisdom of having a single term for both a group or system name and a stage name. Grange's reasons for the introduction of the term Taranakian are detailed in his report on " The Geology of the Tongaporutu-Ohura Subdivision." (1927.) He there states that the " Onairo beds " of his earlier paper (1926) include only a part of the Onairo Series of Clarke (1912), and this part is now distinguished as the " Urenui beds," a name already adopted by Morgan and Gibson. (1927, p. 32 et seq.)

J. Marwick (1924B) provided a stratigraphical table in which the new stage names Tongaporutuan and Onairoan were proposed, without definition, but obviously for the Tongaporutu and Onairo beds of Grange whose unpublished results were available to him. In a later paper (1926A) Marwick used the terms " Tongaporutuan " and " Urenui beds " for the same time interval. Again (1927) he combined both series, and employed solely the stage name Taranakian. J. Henderson (1929), however, has used the term Urenuian, without definition, other than is implied in the name.

Judging from the lists of mollusca published by L. I. Grange (1927)* there would seem to be little palaeontological justification for subdividing the strata in question into two units.

The characteristic mollusca of the Tongaporutu beds appear to be:—*Amusium zitteli* (Hutt.), *Ancilla subhebera* Marwick, *Austrofusus cliftonensis* (Marwick), *Cominella hendersoni* Marwick, *Corbula canaliculata* (Hutt.), *Dentalium pareorense* Pils. and Sharp, *Fissidentalium solidum* Hutt., *Neilo sublaevis* Marwick, *Polinices scalptus* (Marwick), and *Zeacolpus vittatus* (Hutt.)

The characteristic mollusca of the Urenui beds appear to be:—*Ancilla subhebera* Marwick, *Austrofusus cliftonensis* (Marwick), *Dentalium otamaringaensis* Marwick, *Fissidentalium solidum* (Hutt.), *Glycymeris rapanuiensis* Marwick, *Neilo sublaevis* Marwick, *Streptopelma henchmani* Marwick, and *Zeacolpus vittatus* (Hutt.).

Of less importance but still apparently abundant are:—*Alcithoe solida* Marwick, *Cominella hendersoni* Marwick, *Divaricella cumingi* (Ad. and Ang.) *Friginatica vaughani* (Marwick), *Nucula otamaringaensis* Marwick, *Polinices propeovatus* (Marwick), *P. scalptus* (Marwick), and *Zeacrypta wilckensi* (Finlay).

It is only fair to state that these lists are not based upon personal observations in the field, but upon the frequency of occurrence in the many lists of fossils supplied by Grange. It is hardly necessary to state that a fossil recorded from numerous localities is not necessarily abundant at the horizon in question. If my lists do, in fact, include the characteristic fossils, or the majority of them, then the differences between the characteristic communities of the Tongaporutu and Urenui beds respectively are not of great importance. They may indicate a zonal distinction, but do not, in my opinion, necessitate the subdivision of these strata into two stages.*

In consideration of the above facts, and since the correlation of the whole of the strata in N.E. Taranaki is not definitely known, I would advocate that the term Taranakian be retained as a group or system name. *It may be defined as the time interval between the Oamaruian and Wanganuian periods as herein defined.*

As regards the stages to be included in the Taranakian System the position is admittedly difficult.

It is clear, however, that the interval represented by the deposition of the Tongaporutu and Urenui beds does not, even approximately, fill this gap.

The pre-Tongaporutu beds, namely, the Mahoenui, Mokau, and Mohakatino beds, may possibly be post-Oamaruian. Again Morgan and Gibson recorded that the Urenui beds "are succeeded disconformably or possibly with slight angular unconformity by beds assigned to the Waitotara formation." (1927, p. 33.)

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* The nomenclature is that of Grange's bulletin; some generic names require revision.

The strata referred to the Waitotaran by Morgan and Gibson "are known to belong to a lower horizon than the type Waitotara beds of the South Taranaki coast line." (1927, p. 43.) They are, therefore, not strictly Waitotaran. The mollusca cited, however, prove that the beds in question are more closely related in time to the Waitotaran than they are to the Urenuian.

Until the uncertainties implicit in this discussion are cleared up it seems best to employ the terms Tongaporutuan and Urenuian as stage names. If they prove to have identical characteristic fossils they should be combined, and a new term proposed. For this I would suggest a name based upon Rapanui Stream.

The type localities for both stages will, no doubt, be defined in terms of the coast sections between Kawau, Whitecliffs, and Waitara.

Summary:—

System.	Stage.
Wanganuian.	Waitotaran.
Taranakian.	(Possible new stage.) Urenuian. Tongaporutuan. (Possible new stage or stages.)
Oamaruian.	Awamoan.

TONGAPORUTUAN Stage. See Taranakian System.

URENUIAN Stage. See Taranakian System.

WAIAREKAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-35) for the "Waiareka tuffs and Enfield-Windsor greensands = Ngapara greensands" of the Oamaru District. Thomson wrote: "Should this stage be too large in comparison with the others, the Waiarekan may be restricted to the tuffs themselves, and the underlying Windsor and Enfield beds may be made the type of a new stage." (1916, p. 35.)

Thomson's suggestion has, in the main, been carried out, for Marwick (1926 B) has restricted the Waiarekan to the tuffs, selecting Lorne as the type locality; and Allan (1926, 1927) based the Tahuian and Bortonian (of Park) upon greensands in the Waihao Valley which are almost certainly the correlatives of Windsor-Enfield-Ngapara greensands mentioned by Thomson.

Type locality: Marwick has proposed "that the hillside immediately west of Lorne be taken as the type locality" (1926 B, p. 307.) The geological details of this hillside are, judging from Marwick's sketch and from his short description, somewhat obscure, and the locality is hardly ideal for a standard.

Marwick*[1] did not state the relative abundance of the species, therefore the whole fauna is here listed (Marwick, 1926 B, p. 310) :— *Chlamys enfieldensis* Marwick*, *Clavatula humerosa* Marwick, *Diplodonta infrequens* Marwick, *Erato vulcania* Marwick, *Eucrassatella media* Marwick*, *Fossularca januaria* Marwick, *Glycymeris lornensis* Marwick, *Kellia antiqua* Marwick, *Limatula trulla* Marwick, *Lornia limata* Marwick, *Mantellum inconspicuum* Marwick, *Nemocardium semitectum* Marwick, *Polinices esdailei* (Marwick), *Semitriton revolutum* (Finlay), *Serpulorbis lornensis* Marwick, *Sigapatella vertex* Marwick*, *Siliquaria senex* Marwick, *Trivia pinguior* Marwick, *Turricula esdailei* Marwick, *Turritella lornensis* Marwick, *T. tophina* Marwick*, *Venericardia benhami* (Thomson), and *Vexillum lornense* Marwick.

From the nature of the lithology one may infer that this assemblage is a facies fauna, and before placing much value on the Waiarekan Stage one would like to know more of similar facies faunas intercalated with the Ototaran limestones. This fauna has never been recognised apart from its peculiar facies, and it may prove that the Waiarekan should be merged with the Ototaran Stage (cf. Henderson (1929), p. 273). This is another problem for future research*[2].

WAIMANGAROAN System. See Mawheranuian System.

WAIMATEIAN Stage.

Proposed by Allan (1926) for the pre-Ototaran marine beds in the Lower Waihao Valley, South Canterbury. It was subdivided into the Tahuian and Bortonian substages. The latter have since been granted the rank of full stages by J. Marwick (1927, p. 573); hence the term Waimateian may lapse.

WAIPIPIAN Stage. See Wanganuian System.

WAITAKIAN Stage.

Proposed by J. Park (1918, p. 25) as a substage of the Hutchinsonian Stage of Thomson, in the following words: " On palaeontological grounds the Hutchinsonian might be divided into two substages—the lower or true Hutchinsonian including the glauconitic greensands, the upper comprising the glauconitic calcareous sandstone that forms the Waitaki stone or Waitakian." (1918, p. 25.)

This definition, as a perusal of Bulletin No. 20 will show, implies the correlation of the Waitaki limestone with certain glauconitic sandy beds below the shell-bed at Target Gully, and these sandy beds

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* Marwick (1931, p. 6) reaches a very similar conclusion.

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*[1] Marwick (1931, p. 4) cites four species of characteristic mollusca. These are followed by an asterisk in the above list.

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*[2] See Marwick (1931, p. 4).

overlie the Hutchinsonian *parki* greensands. The Waitaki limestone, on the other hand, is known to contain a brachiopod fauna which is definitely pre-Hutchinsonian. (Thomson, 1926.)

The term Waitakian, therefore, connotes two distinct stratigraphical units, and if it is to be retained must be restricted to one or the other.

It is rather doubtful whether a new division is required for the so-called Waitakian of Target Gully. The stratigraphy is not clear in the locality, and G. H. Uttley (1920 B) has argued that Park's Upper Hutchinsonian there is in fact Awamoan. In my opinion the area should be thoroughly reinvestigated before a decision can be reached.

On the other hand, a new or distinct term is certainly required for the Waitaki limestone and the overlying Otiake beds of the Waitaki Valley. Professor Park has spent many years in attempting to prove that the Waitaki limestone is distinct from the limestones of the Oamaru Coastal District, therefore it will be fitting to employ his term, Waitakian, for the former unit. The Waitakian may be granted the rank of a full stage intermediate in position between the Hutchinsonian and the Ototaran.

One may venture to hope that this decision, based upon the combined researches of J. Park, G. H. Uttley, and J. Allan Thomson, will bring to an end the somewhat lengthy controversy which has centred around the " two limestone theory " in the Oamaru District.

The Waitakian may be defined as the interval of time represented by the deposition of the Waitaki limestone and the Otiake beds of the Waitaki Valley, and as well such periods as may be represented therein by non-deposition or erosion.

It is difficult to select a locality in the Waitaki Valley which will provide a complete section of strata contained in the Waitakian Stage. Perhaps Trig. Z., Otiake, comes nearest to the ideal. I select that locality (see Uttley, 1920 A, Fig. 2 on p. 143) as type.

The brachiopod fauna of this stage cannot be listed in detail. It consists of species of the *Pachymagas huttoni* series. The Waitakian overlies strata containing the *Liothyrella landonensis* fauna, and does not contain any species referable to the *Pachymagas parki* series.

Mollusca are rare in the limestone, but very abundant in the overlying Otiake beds.

The characteristic mollusca, based upon collections made by Dr. H. J. Finlay and the writer, and named by the former, include:—*Alocospira hebera* (Hutt.), *Austrofusus affiliatus* Finlay, *Badenia zebina* Finlay, *Baryspira robusta* Marwick, *Cochlis inexpectata* (Finlay), *C. notocenica* (Finlay), *Corbula humerosa* Hutton, *C. kaiparaensis* Suter, *Cucullaea worthingtoni* Hutton, *Dosinula uttleyi* Marwick, *" Euthria " blandiata* Suter, *Fissidentalium solidum* (Hutt.), *Friginatica vaughani* (Marw.), *Gari oamarutica* Finlay, *Globisinum miocaenicum* (Suter), *Kuia vellicata* (Hutt.), *Lentipecten hochstetteri* (Zittel), *Macoma robini* Finlay, *Magnatica planispira* (Suter), *Marginella harrisi* Cossm., *Mesalia striolata* (Hutt.), *Metamelon inermis* (Finlay), *Notocallista parki* Marwick, *Ostrea (Gigantostrea) wollastoni* Finlay, *Panope worthingtoni* (Hutt.), *Parasyrinx subalta* (M. & M.), *Poirieria primigena* Finlay, *Polinices obstructus* (Marw.), *Procominula densilirata* Finlay, *Proximitra armorica* (Suter), *Rugobela tenuilirata* (Suter), *Spinomelon residua* (Finlay), *Spissatella trailli* (Hutt.), *Teredo heaphyi* Zittel, *Teremelon tumidior* (Finlay), *Trachycardium waitakiense* Suter, *Waimatea transilis* Finlay, *Zeacrypta wilckensi* (Finlay), *Zeacuminia biplex* (Hutt.), *Zenatia acinaces* Q. & G., and *Zexilia dalli* (Suter).

WAITOTARAN Stage. See Wanganuian System.

WANGALOAN Stage*.

Proposed by P. G. Morgan (1918, p. 40) and employed by J. Marwick (1924 A, p. 172), in both cases without definition, but obviously based upon the "Wangaloa beds" of P. Marshall (1917, pp. 450-60).

Type locality: Wangaloa, Otago.

Precise stratigraphical details of the sequence at Wangaloa will no doubt be found in the forthcoming Survey Bulletin dealing with this area.

The fauna has been described by Marshall (1917), but the nomenclature needs considerable revision.

Recently H. E. Fyfe has discovered an identical fauna, well preserved, at Boulder Hill, near Dunedin. Material from this locality, as well as from Wangaloa, is being described by Dr. H. J. Finlay in collaboration with Dr. J. Marwick, and this report should be published in the near future.

Pending the information to be derived from the two sources indicated, it will be sufficient to state that the fauna of the Wangaloan Stage is the oldest Tertiary fauna known in New Zealand, and that its characteristic mollusca are almost entirely distinct from any that follow them in the Dominion.

Until Marshall's determinations are revised it would be premature to cite a detailed list of the mollusca. Those recently described by Marwick (1924, 1927) may be noted. All (except one) are confined to the Wangaloan Stage, but are not necessarily abundant. They are:—*Amauropsella major* (Marshall), *Dosinia (Kereia) ongleyi* Marwick, *D. perplexa* Marwick, *Finlaya parthiana* Marwick, *Globisinum spirale* (Marshall), *Monalaria minor* (Marshall), *Polinices finlayi* (Marwick), *P. (Euspira) fyfei* (Marwick), and P. *(E.) firmus* (Marwick).

The last named is also found in the Bortonian.

WANGANUIAN System.

Proposed by J. Park (1910) for the sequence of strata exposed on the sea coast between Wanganui and Patea, and adopted by J. A. Thomson (1916).

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*Marwick (1931, p. 3) supplies additional data concerning this stage.

The sequence of strata on the Wanganui coast based on J. Park's survey (1887) is as follows, re-quoted from Thomson (1916, p. 36) :—

Park, 1887.		Park, 1905.	Park, 1910.
(1.) Wanganui beds: Upper sandy beds. Lower blue clays.	Newer Pliocene.	Wanganui Series.	Petane Series.
(2.) Kai-iwi blue clays.			
(3.) Okehu pumice beds.			
(4.) Okehu sandy shell beds.			
(5.) Nukumaru Rotella beds.			
(6.) Nukumaru limestone—Older Pliocene.			
(7.) Waitotara Coralline Series: Brown micaceous sandstone. Coralline beds. Yellowish-blue sand clays. Whenuakura blue clays.	Upper Miocene	Te Aute or Waitotara Series.	Waitotara Series. Awatere Series.
(8.) Patea blue clays and brown sands.			

Thomson (1916) based two stage names upon this succession, viz., Castlecliffian for the Wanganui beds and Kai-iwi blue clays, and Waitotaran, based oupon Park's " Waitotara Coralline series." The limit between these stages was purposely, and wisely, left vague.

Marshall and Murdoch (1920) published an excellent account of the faunal changes throughout the Wanganuian, but did not employ stage names.

In a table of classification of strata, prepared by P. G. Morgan (?) and published in a Bulletin by T. H. Withers (1924), it is stated that the Waitotaran " may be subdivided into Nukumaruian and Waipipian," and a footnote adds: " Probably the term ' Waitotaran ' as a stage name will drop out of use, and the more exact terms ' Nukumaruian ' and ' Waipipian,' based upon Marshall and Murdoch's work (1920) will take its place."

L. I. Grange (1926, p. 334, footnote) has pointed out that this is impossible since Thomson (1916) did not include the Nukumaru beds in his Waitotaran Stage. The Waipipian is the term which must drop out of use.

Marwick (1924 A) divided the Wanganuian into Waipipian, Nukumaruian, and Castlecliffian, but in a later paper (1924 B) Waitotaran was substituted for Waipipian. The same author (1926 A, p. 267) later separated off the Kai-iwi beds because " a preliminary survey indicates that a useful stage may be recognisable between the Nukumaruian and Castlecliffian." Thomson (1916), however, included the Kai-iwi beds in the Castlecliffian. Marwick's latest scheme (1927) distributed the stratigraphical units as follows:—

(a.) Castlecliffian, containing the Castlecliff, Kai-iwi, and Okehu beds.

(b.) Nukumaruian, the Nukumaru beds.

(c.) Waitotaran, all lower divisions on the Wanganui coast.

These various stage names, therefore, have been employed rather loosely, and should be redefined. It is generally admitted that three stages are represented in the sequence, and for these the terms Castlecliffian, Nukumaruian, and Waitotaran have found general acceptance. It is probable that future research will prove that each of these stages contains more than one faunal community. The exact range of these communities is not yet accurately known. However, the writer believes that it would be wise to define the three stages with reference to certain definite stratigraphical units. The minor faunal communities, when their range is established, can form the basis of zones within the major scheme here outlined.

The Castlecliffian may be defined as the interval of time represented by the deposition of the Wanganui, Kai-iwi, and Okehu beds of Park (1887), and as well such periods as may be represented therein by non-deposition or erosion.*

Henderson (1929) has noted that the lowest beds of the Castlecliffian contain much pumice, and a seam of lignite. He believes that the Castlecliffian strata result from a minor sea transgression which followed uplift at the end of the Nukumaruian period. If this is so the Nukumaruian-Castlecliffian junction may conceal a considerable time interval.

The characteristic mollusca of the Castlecliffian based upon collections made by the writer, and further material in the Finlay collection, and determined by Dr. Finlay, are† :—*Acteon ambiguus* (Hutt.), (= *sulcata* Hutt.), *Aeneator marshalli* (Murdoch), *Alcithoe gracilis* (Swainson), *A. swainsoni* Marwick, *Alocospira novaezelandiae* (Sow.), *Amphidesma pliocenica* Oliver, *Antisolarium egenum* (Gould), *Arthritica bifurca* (Webster), *Astrea heliotropium* (Martyn), *Ataxocerithium huttoni* (Cossm.), *Austrodrillia wanganuiensis* (Hutt.), *Austrofusus glans* (Bolten), *Barbatia novaezelandiae* Smith, *Baryspira (Pinguispira) lata* (Hutton), *B. mucronata* (Sow.), *Cardita aoteana* Finlay, *Chlamys radiatus* (Hutton), *Cochlis australis* (Hutt.), *C. zelandica* (Q. & G.), *Coelotrochus huttoni* (Cossm.), *Coluzea spiralis* (A. Ad.), *Corbula macilenta* Hutt., *Cosa wanganuica* Finlay, *Divaricella cumingi* Ad. and Ang., *Dosinia (Phacosoma) wanganuiensis* Marwick, *Dosinula zelandica* (Gray), “ *Drillia* ” *buchanani* (Hutt.), *Estea impressa* (Hutt.), *E. semisulcata* (Hutt.), *Eucominia elegantula* Finlay, *Evarnula striata* (Hutt.), *Gari lineolata* (Gray), *Glaphyrina progenitor* Finlay, *Glycymeris laticostata* (Q. & G.), *Iredalula striata* (Hutt.), *Mantellum marwicki* Powell, *Maoricolpus roseus* (Q. & G.), *Maoricrypta costata* (Sow.), *Maurea hodgei* (Hutt.), *Melliteryx parva* (Deshayes), *Murexsul octogonus* (Q. & G.), *Myadora striata* (Q. & G.), *Nemocardium pulchellum* (Gray), *Notocallista multistriata* (Sow.), *Notolepton antipodum* (Filhol), *Nuculana bellula* (A. Ad.), *Ostrea sinuata* Lam.,

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* In this connection see Marwick (1931, pp. 7-8).

† This list is characteristic of the Upper Castlecliffian only—records of common species at Kai-iwi are not available to me.

Pachykellya edwardsi Bernard, *Panope zelandica* Q. & G., *Paphirus largillierti (Philippi)*, *Pelicaria vermis* (Martyn), *Phenatoma novaezelandiae* (Reeve), *Pleuromeris zelandica* (Deshayes), *Poirieria zelandica* (Q. & G.), *Pteronotus zelandicus* (Hutt.), *Saxicava australis* Lam., *Scalpomactra scalpellum* (Reeve), *Semicassis multisecta* (Finlay), *Sigapatella inflata* (Hutt.), *Splendrillia laevis* (Hutt.), *Stirocolpus symmetricus* (Hutt.), *Struthiolaria papulosa* (Martyn), *Tawera wanganuiensis* Marwick, *Tellina eugonia* Suter, *T. urinatoria* Suter, *Tugali pliocenica* Finlay, *Venericardia purpurata* (Desh.), *Verconella mandarina* (Duclos), *Xymene plebeja* (Hutt.), *Zeacolpus vittatus* (Hutt.), *Zeatropon ambiguus* (Phil.), *Z. bonneti* (Cossm.), *Zemitrella sulcata* (Hutt.), *Zemysia zelandica* (Gray), *Zenatia acinaces* Q. & G., and *Zethalia zelandica* (A. Adams).

The Nukumaruian may be defined as the interval of time represented by the deposition of the Nukumaru beds as exposed on the Wanganui coast, and as well such periods as are represented therein by non-deposition or erosion.

The characteristic mollusca of the Nukumaruian Stage, based upon personal collections from the type locality, Nukumaru, and determined by Dr. Finlay, are:—*Alcithoe detrita* Marwick, *A. nukumaruensis* (M. & M.), *Anomia undata* Hutton, *Austrovenus crassitesta* Finlay, *Baryspira (Pinguispira) lata* Hutt., *B. (P.) opima* Marwick, *M. mucronata* (Sow.), *Bassina yatei* (Gray), *Cominista obsoleta* Finlay, *Corbula macilenta* Hutt., *Cosa trigonopsis* (Hutt.), *Dosinia (Raina) nukumaruensis* Marwick, *Dosinula zealandica* (Gray), *Estea semisulcata* (Hutton), *Eucominia exoriata* Finlay, *Isognomon zelandicum* (Suter), *Lutraria solida* Hutt., *Maorimactra acuminella* Finlay, *Ostrea sinuata* Lam., *O. (Crassostrea) ingens* Zittel, *Pallium mariae* Finlay, *Pervicacia tristris* (Deshayes), *Pleuromeris zelandica* (Desh.), *Pteromyrtea dispar* (Hutt.), *Tawera subsulcata* (Suter), *Venericardia purpurata* (Desh.), *Verconella allani* Finlay, *Xymene drewi* (Hutt.) and *Zethalia zelandica* (A. Adams).

The Waitotaran may be defined as the interval of time represented by the deposition of the pre-Nukumaruian strata exposed on the Wanganui coast, and as well such periods as are represented therein by non-deposition or erosion.*

An incomplete list of the characteristic mollusca is as follows:—*Alcithoe gatesi* Marwick, *Cardium spatiosum* (Hutt.), *Cochlis haweraensis* (Marwick), *Dosinia (Raina) waipipiensis* Marwick, *Eumarcia plana* Marwick, *Fissidentalium solidum* (Hutt.), *Glycymeris manaiaensis* Marwick, *Lima waipipiensis* (M. & M.), *Miltha neozelanica* M. & M., *Olivella neozelanica* (Hutt.), *Ostrea (Crassostrea) ingens* Zittel, *Pallium mariae* Finlay, *Pelicaria zelandiae* (M. & M.), *Phialopecten triphooki* (Zittel), *Polinices ovuloides* (Marwick), *P. waipipiensis* (Marwick) and *Tawera errans* Marwick.

The stages of the Wanganuian are somewhat loosely defined. The writer believes that further research on this classic coast line is necessary before greater precision can be obtained. A continuation of the excellent work carried out by Marshall and Murdoch is most desirable.

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* See Marwick (1931, p. 7).

T. Wayland Vaughan (1921, p. 738) has suggested that the Wanganuian faunas might logically be discussed with reference to the disconformities noted near Kai-iwi, and at Nukumaru Beach, by Marshall and Murdoch (1920). This has not yet been attempted.

III.—SUMMARY OF CLASSIFICATION.

The classification resulting from the discussions detailed above may be summarised in table form. Diastems or disconformities are indicated by a dotted line (....). New stages may prove necessary at these intervals.

System or Group.	Stages.
Wanganuian.	Castlecliffian.
	....................(1)
	Nukumaruian.
	Waitotaran.
Taranakian.	....................(2)
	Urenuian.
	Tongaporutuan.
	....................(3)
Oamaruian.	Awamoan.
	....................(4)
	Hutchinsonian.
	....................(5)
	Waitakian.
	Ototaran.
	Waiarekan.
	Tahuian.
	....................(6)
	Bortonian.
Kaitangatan (pars).	....................(7)
	Wangaloan.

The following are non-marine stages:—Brunnerian, Ngaparan, and Paparoan.

The following terms are rejected as being unnecessary, imperfectly defined, or otherwise invalid:—Awaterian, Islandian, Kaiatan, Mawheranuian, Onairoan, Pareoran, Petanian, Waimangaroan, Waimateian, and Waipipian.

Some notes follow on the diastems and disconformities in the table. These are numbered 1 to 7, and will be considered in that order.

No. 1.: Between the Castlecliffian and Nukumaruian. Henderson (1929) believes that the junction of the strata referred to these stages in the type locality conceals a time break during which the main Kaikoura movements occurred.

Between the Waitotaran and the Urenuian. Morgan and Gibson (1927) record that the Urenui beds are succeeded disconformably by beds assigned to the Waitotaran, but these beds " assigned to the Waitotaran " " are known to belong to a lower horizon than the type Waitotara beds of the South Taranaki coast line." (1927, p. 43.)

No. 3.: Between the Tongaporutuan and the Awamoan. It may prove that part of the pre-Tongaporutuan beds of Taranaki are post-Awamoan.

No. 4.: Between the Awamoan and Hutchinsonian. Unpublished evidence proves that the Awamoan-Hutchinsonian boundary in the Oamaru Coastal District conceals a long time interval. The bulk of the Clifden beds, the Pakaurangi Point beds*, and other strata were deposited at this time. Further details will appear in a future paper by Dr. H. J. Finlay and the writer.

No. 5.: Between the Hutchinsonian and the Waitakian. This break is postulated because it is not certain that the Waitakian completely fills the interval between the Ototaran and the Hutchinsonian. No junction between strata of Waitakian and Hutchinsonian age is yet known.

No. 6.: Between the Tahuian and Bortonian. The phosphatised upper surface of the Bortonian greensands at McCullough's Bridge no doubt indicates a diastem. Judging by palaeontological evidence any break at this junction must be of small time significance.

No. 7.: Between the Bortonian and the Wangaloan. The mollusca of these stages have little in common. The inference is that a considerable time interval separates them.

IV.—SOME GENERAL CONCLUSIONS.

In an excellent summary of the Late Cretaceous and Tertiary Rocks of New Zealand, J. Henderson (1929) suggested that the strata in question " are divisible into three groups on diastrophic grounds. The youngest, deposited after the main Kaikoura movements had ceased, form the Castlecliff beds, and their correlatives in other parts of New Zealand. The other and much more important groups were laid down during the relatively quiescent period between the Hokanui and Kaikoura orogenies." (1929, p. 294.)

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* Marshall. 1918.

If I understand it correctly, Henderson's thesis may be summarised as follows:—

1. Castlecliffian (minor sea transgression).

......................main Kaikoura movements.

2. Hutchinsonian to Nukumaruian (period of sea retreat).
3. Late Cretaceous to Ototaran (period of sea transgression and base levelling).

..........................Hokanui movements.

Henderson stated that "the erosion interval above the Ototaran beds . . . is taken as separating one group of beds from the other" (i.e., two from three). The reasons are (1) that the Ototaran deposits are the most calcareous of any sets of beds; (2) that they were deposited during the period of maximum sea transgression; and (3) that a great change in the position of the areas where waste accumulated occurred after the close of the Ototaran. (1929, p. 294.)

These conclusions are open to serious criticism:—

(1.) Because they are based upon very questionable correlations.

(2.) Because the Waitakian Stage, intermediate between the Ototaran and Hutchinsonian, is not considered.

In the Hutchinsonian Henderson includes (a.) the Pakaurangi Point beds; (b.) the Mahoenui beds of Taranaki; (c.) the Ihungia Series of the East Cape; (d.) the Lower Mount Brown beds; (e.) the Hutchinson's Quarry beds; and (f.) the bulk of the Clifden beds.

Of these (d.) and (e.) are undoubtedly Hutchinsonian, but the others are all doubtful.

Henderson further included the Winton and Clifden limestones in the Ototaran, whereas both contain very typical Hutchinsonian brachiopod assemblages.

The bulk of the strata at Clifden, as well as the Pakaurangi Point beds, and the uppermost Mount Brown beds are post-Hutchinsonian, but pre-Awamoan.

I must conclude from these facts that the problem is much more complicated than Henderson infers. A single marine transgression and retreat with the Ototaran rocks representing the period of maximum transgression hardly meets the case.

In the South Island, at least, Hutchinsonian rocks are more widespread, and just as calcareous as the Ototaran.

Concerning the relationship of the Castlecliffian to the Kaikoura orogeny, the only evidence I can find in Henderson's paper follows from the correlation of the Waipaoa Series of the East Cape with the Castlecliffian.

The reason for this correlation is not given. Henderson and Ongley (1920, pp. 50-51) both regard the Waipaoa Series as Older Pleistocene*.

Additional details of the fauna and flora of the Waipaoa Series are provided by W. R. B. Oliver (1928). As far as the mollusca are concerned the sole evidence for the Castlecliffian age of the series consists of the presence of *Acteon sulcatus* (Hutt.). From his palaeobotanical studies, however, Oliver concluded that the age of the Waipaoa Series was " not younger than later Pliocene." (1928, p. 288.)

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* The latter authors add that this series belongs "perhaps to the Upper Pliocene."

This evidence appears to the writer to be altogether inconclusive. The correlation of the Castlecliffian and the Waipaoa Series upon the molluscan evidence—a single species—is most questionable. Correlation between these two units on palaeobotanical evidence is impossible. If Oliver's conclusion be accepted it does not follow that the two units are correlatives. Both could be " Upper Pliocene " without being equivalent.

Henderson's conclusion concerning the date of the Kaikoura orogeny can hardly be accepted on the data presented.

In this paper most weight has been given to the communities of mollusca and brachiopoda. The Tertiary foraminifera, shark's teeth, and cirripedes have been described, but as far as I can judge are not of much value for purposes of correlation. It is a matter of regret that the bryozoa, corals, and echinoderms are very imperfectly known. Bryozoa in particular are very abundant in our Tertiary rocks, and might well provide valuable data.

It may be suggested with some reasonableness that the adjectival form such as Ototaran, Tahuian, etc., should be reserved by stratigraphers for stage names. If, as has been the case, adjectival terms are used for local series, confusion will be inevitable.

Thus M. Ongley (1924, p. 171) has used the term Ihungian for the Ihungia Series of the Waiapu Subdivision. (Ongley and Macpherson, 1928, pp. 35-9.)

Finlay and McDowall (1924, p. 536) wrote " Mokauian " instead of Mokau beds.

Again Morgan (1921, p. 5), Powell and Bartrum (1929), and Henderson (1929, p. 277) have used the term " Waitematan " instead of " Waitemata beds."

None of the authorities cited intended to propose new stage names, but why add difficulties to what is already a sufficiently difficult matter?

Finally the writer puts forward a plea for greater accuracy in the use of stage names. These are scientific terms, and should have a precise meaning. In particular new stage names should not be proposed unless stratigraphical or palaeontological evidence demonstrates clearly that they are necessary.

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On Three Species of Delesseriaceæ from New Zealand.

By HARALD KYLIN, Lund, Sweden.

[*Communicated by Mr R. M. Laing. Read before the Philosophical Institute of Canterbury, 4th November, 1931; received by Editor, 5th November, 1931; issued separately, 28th February, 1933.*]

SOME years ago I obtained from Mr R. M. Laing a collection of New Zealand species of Delesseriaceae in order to verify the determination of the different species. My determinations are published in a previous paper (1929). Since then I have got some more species of Delesseriaceae, and in consequence thereof I have some more remarks to make about three New Zealand species of this family.

ERYTHROGLOSSUM UNDULATISSIMUM (J. Ag.) Kylin nov. comb.

Nitophyllum undulatissimum J. Ag. (1898) Sp. Alg. III: 3 p. 59; *Myriogramme undulatissima* Kylin Deless. p. 60, Kylin Deless. Neu Seeland, p. 9, taf. 6, fig. 14.

This species was for the first time collected in New Zealand by F. von Müller in 1885 and described by J. Agardh in 1898, who, with a question mark, referred it to the genus *Nitophyllum.* Later on Kylin referred it to the genus *Myriogramme,* described by himself in 1924.

Photographs of the species in question are published by Kylin (1929, taf. 6, fig. 14). The type-specimens are not good, and therefore it is difficult to make sure of the genus to which this species is to be referred. In the above mentioned collection of Laing there was, however, a specimen because of which I doubted the correctness of referring the species in question to *Myriogramme* (Kylin 1929, p. 9).

Now I have some dried specimens of *Nitophyllum undulatissimum* J. Ag. as well as some ones preserved in alcohol. They are sent by Laing, who found them cast ashore in Lyttelton Harbour, New Zealand, on the 13th July, 1930. The material preserved in alcohol has made it possible to study the growing points. In the growing point there is always a special apical cell which downwardly by transversal walls is cutting off segment-cells. Immediately below the growing point there occurs a lot of intercalary cell-divisions.

In each lobe of the frond there is a macroscopic main-rib; neither side-nerves nor microscopic nerves are to be found. It is, however, possible that the main-rib in a side-lobe resembles a side-nerve, but there is no connection between a side-nerve of this kind and the midrib in the main-lobe. All branching of the frond starts from the frond-margin.

The above mentioned vegetative characters prove that *Nitophyllum undulatissimum* is to be referred to the genus *Erythroglossum,* and not to the genus *Myriogramme,* as in the latter genus a special apical cell is never to be found in the growing point of the frond.

The development of the procarps in *Erythroglossum undulatissimum* takes place in the same way as in the genus *Myriogramme* (Kylin 1924, p. 56). The cystocarps are scattered over the surface of the frond. In the gonimoblast-filaments are many carpospores ranging one after the other. The tetrasporangia occur in a single row of roundish or elliptical sori, 0, 5 mm. in diameter, between the main-rib and the margin of the frond, generally somewhat nearer the margin.

ERYTHROGLOSSUM LAINGII Kylin nov. spec.

Frond 8-10 cm. high, light red, flat, membranous, much laciniate; the main-laciniae 4-6 mm. broad, with a macroscopic mid-rib, but without side-nerves or microscopic nerves; the ultimate laciniae 4-8 mm. long and 1 mm. broad, with a mid-rib, but without side-nerves or microscopic nerves; all branching of the frond starts from the frond-margin; growing point with a special apical cell, immediately below the growing point there occurs a lot of intercalary cell-divisions in the same way as in *Erythroglossum undulatissimum;* cystocarps and tetraspores unknown. Specimens from New Zealand, Lyttelton, Governor's Bay; drift 28th July, 1929; R. M. Laing.

ABROTEIA SUBORBICULARIS Harv.

Abroteia suborbicularis Harv. (1855) Fl. Nov. Zel. 2 p. 242; *Nitophyllum ? suborbiculare* Harv. l. c.; *Abroteia orbicularis* J. Ag. Epicr. p. 694; *Myriogramme oviformis* Kylin Deless. Neu Seel. p. 9, taf. 6, fig. 13.

In my paper about the New Zealand Delesseriaceae I described a new *Myriogramme* species under the name of *M. oviformis.* Later I found, however, that this species was earlier described by Harvey under the name of *Abroteia (Nitophyllum ?) suborbicularis.* The genus *Abroteia* seems to be nearly related to *Myriogramme.*

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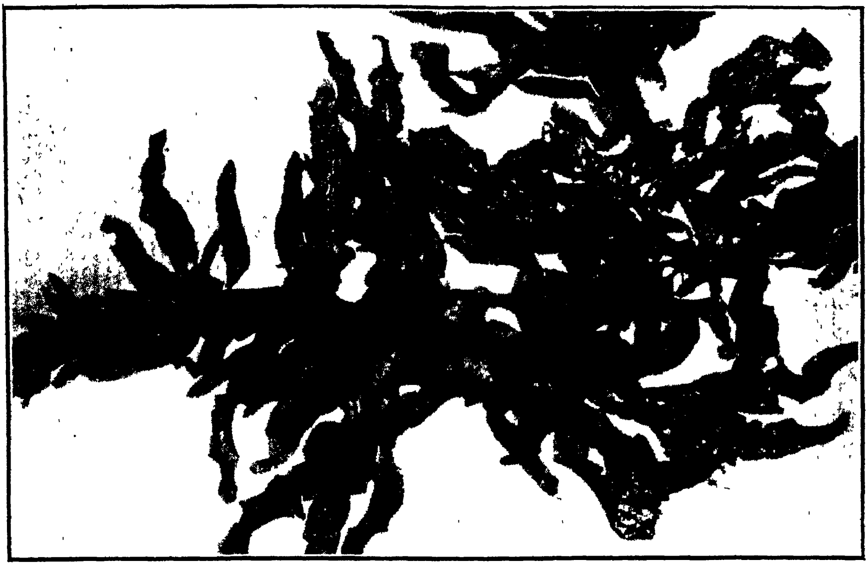

FIG. 2.—*Erythroglossum undulatissimum* with cystocarps. Natural size.

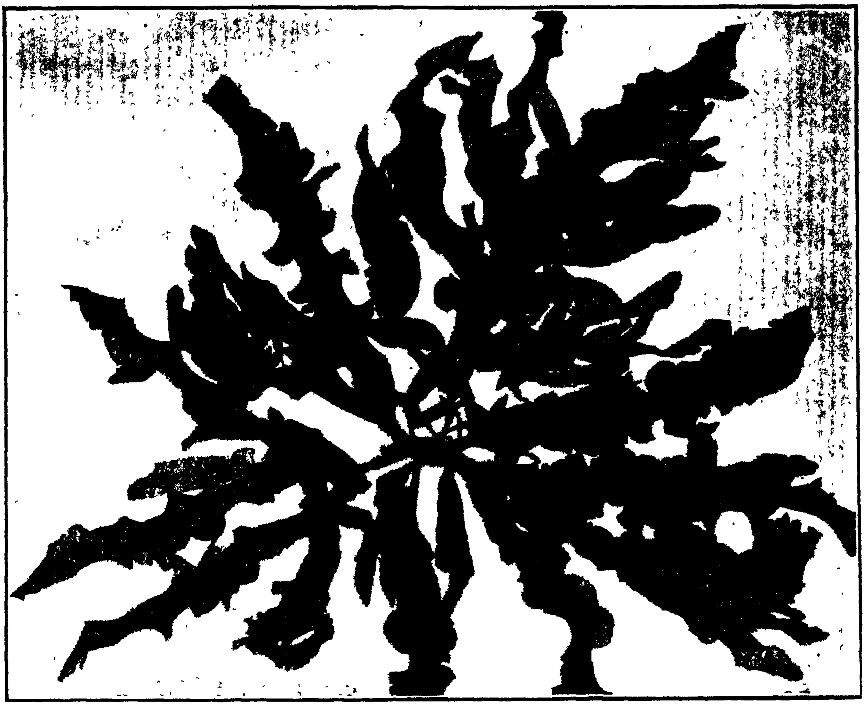

FIG. 3.—*Erythroglossum undulatissimum* with tetraspores. Natural size.

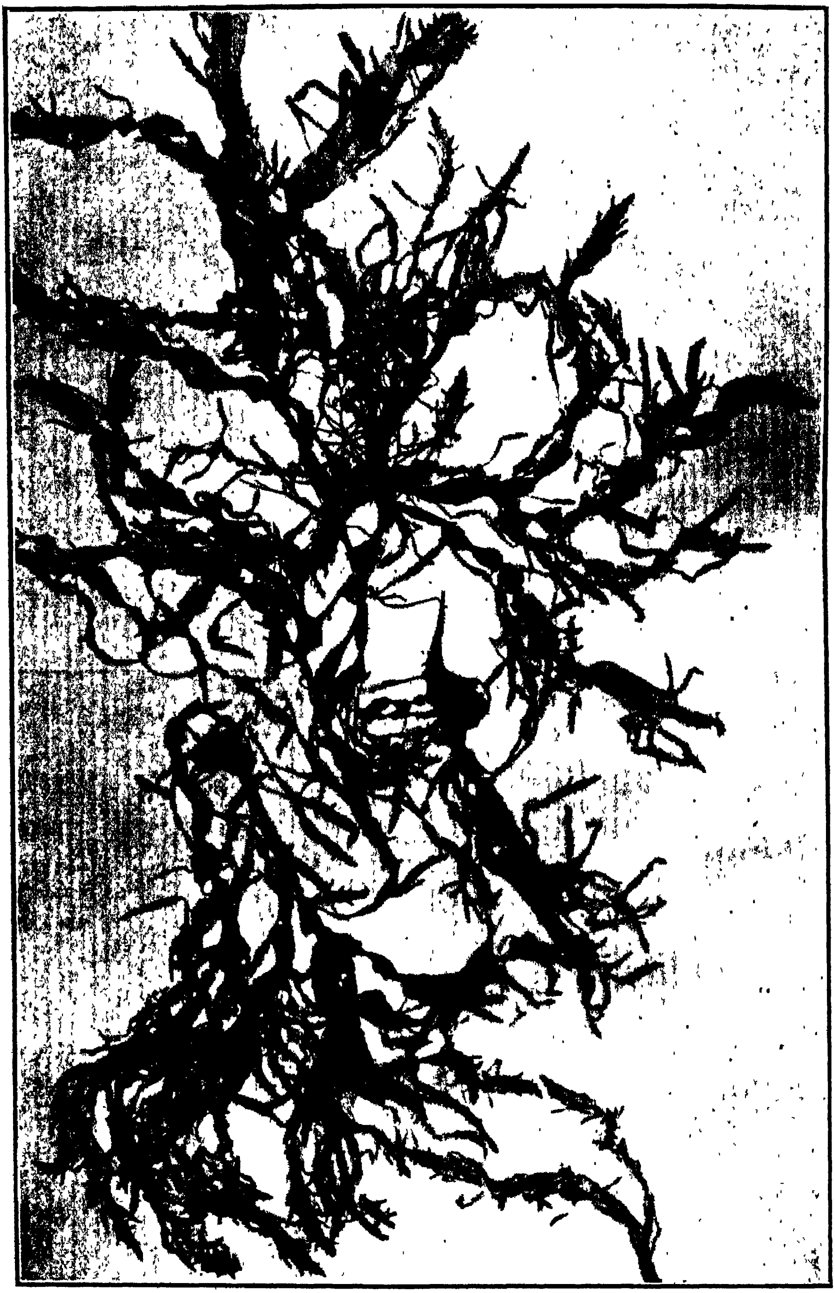

FIG. 4.—*Erythroglossum Laingii.* Nine-tenths natural size.

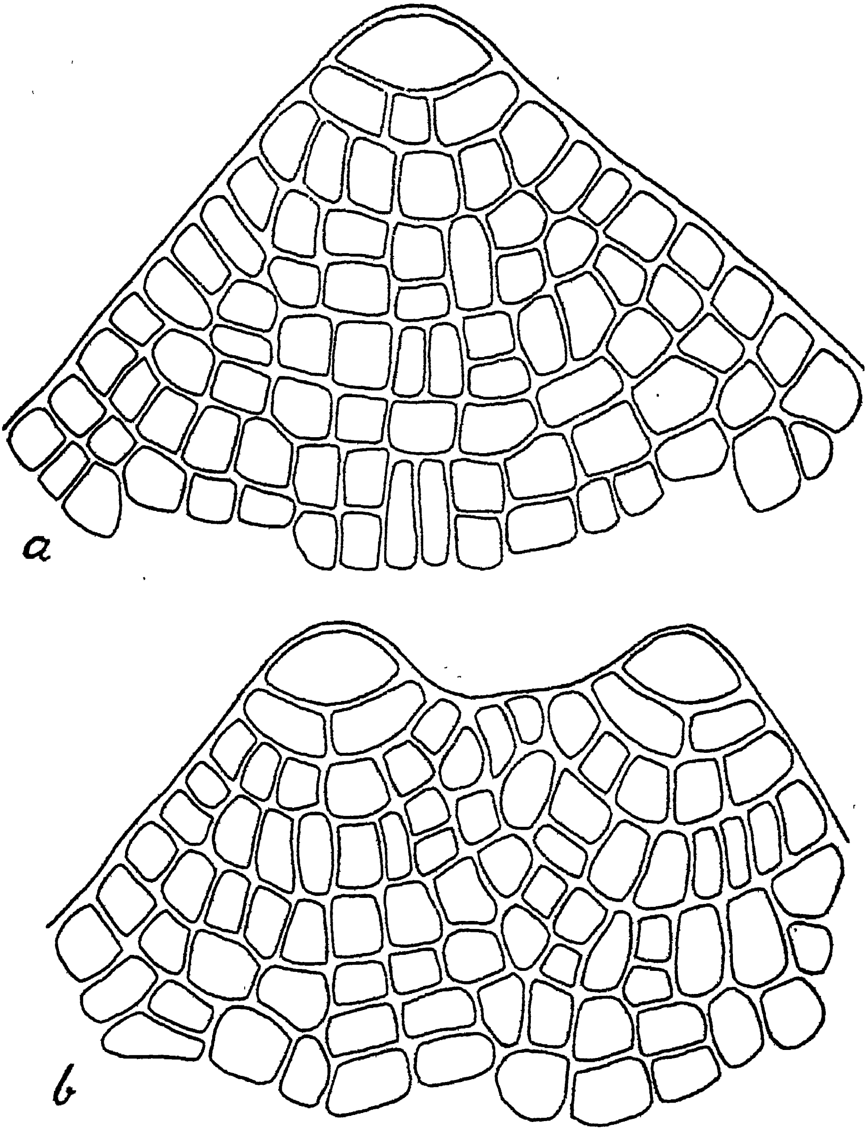

FIG. 1.—*Erythroglossum undulatissimum* growing points × 400.

The Lepidoptera of the Te Anau-Manapouri Lakes Districts.

By Charles E. Clarke, F.E.S.

[*Read before the Auckland Institute, 16th December, 1931; received by the Editor, 4th February, 1932; issued separately, 28th February, 1933.*]

The large expanse of mountainous and densely-wooded country which almost encircles Lakes Manapouri and Te Anau is best reached by overland travellers from both Dunedin and Invercargill by taking a road that branches to the west at the base of the Takitimo Mountains. This road crosses the Mararoa River at " The Key of the Lakes," and proceeds through the " Wilderness " to diverge again after a mile or two, a branch from the Te Anau trail striking north at the Whitestone River to meet the valley of the Eglinton.

The many series of precipitous crags and ranges converging on the lakes are mostly accessible by climbing the wooded spurs that lead to the subalpine, but the difficulties of transit from one alpine meadow to another render it necessary usually to descend to the lake level before making another ascent, this being the method I have pursued almost invariably, with four to six-day excursions to the heights.

The tracks to Milford and Doubtful Sounds are the most frequented localities of these mountains, and seldom do tourists venture to other parts, although the scenic attractions are of great beauty and exhibit a diversity of interests.

In such a wide field, containing so many unnamed and almost untrodden peaks, it is certain that many new species remain to be discovered, my own experience being that every locality visited has added a quota of new material.

My collecting in these sanctuaries has usually included the traversing of the Milford Track from Glade House to the Sound, which I have done on four occasions, with an excursion or two each time to other places on the way. These visits have been always in December and January, excepting one in October to the Takitimos, and one to the Eglinton River and then the McKinnon Pass in February. It is more than 20 years since my first visit to the Milford Track, since when the following expeditions to various parts elsewhere in this region have been made:

In 1923, with Mr Stuart Lindsay, a camp was made in the Hope Arm, Lake Manapouri, and on two occasions we climbed the Hunter Mountains.

In 1925, to the Waiau River from Tuatapere, and then to the Takitimo Mountains.

In 1926, with Mr R. Milnes, across the Milford Track to the Sound and to the subalpine of Mount Skelmorlie, also to the Takitimos.

In 1927, to the valley of the Eglinton River, and then to the end of the South Arm, Lake Te Anau, from whence I climbed an unnamed mountain of the Kepler Mountains.

In 1928 I returned to Hope Arm, climbing Flat Top Mountain to its summit at about 5000 feet. This was a particularly productive expedition.

In 1929, with Mr Arthur Richardson, I camped at the Worsley Stream and climbed Mount Kemp to the subalpine, after which we went to the Milford Track, collecting again on the Clinton and Arthur Rivers, and on McKinnon Pass.

I have at various times visited the Oreti, Mararoa, Whitestone, and Spey Rivers, as well as the "Five Lake" swamps near Manapouri.

The favourite collecting field, however, was the McKinnon Pass, and the ease with which it may be reached made it a welcome rendezvous always.

The prevailing beech (Nothofagus) forest extends up the slopes to an altitude of a little over 3500 feet, mixed bush being found generally on the outskirts and along rivers, the nature of the vegetation abruptly changing again above the bush line, above which the most interesting collecting is obtained.

The subalpine meadows are of great beauty with their flowers and colour generally, and sometimes extend for miles among the ridges, but are usually broken by the presence of screes and arêtes and precipitous pinnacles, so that upland investigation presents many difficulties to the travelling entomologist. I found it best to establish base camps and only climb with bivouac tent and light equipment, usually to make four-day raids on the heights. A dry shelter under a giant boulder can be found without difficulty, and the presaged certainty of discovering new and interesting specimens is at the same time enhanced by the pleasure of dwelling temporarily in a rock-garden of rare beauty, conspicuous among the species of flowering plants being Celmisias, Ranunculus, Gaultherias, Senecios, Olearias, and other handsome plants, as well as the particular friends of the entomologist, the Veronicas and Dracophyllums, whose blossoms are so attractive to insects.

At from 3000 to 4000 feet elevations, in sheltered positions above the forests, local tracts of peculiar plant associations nurture the most desiderata, and there is a tendency for otherwise uncommon species to be favoured and form colonies, distinct types of local species occasionally being apparently confined to one particular locality.

In more or less isolated upland "overhanging valleys" semi-apterous tendencies are prevalent, and in two such places I visited —on Flat Top Mountain, Hunter Mountains, Lake Manapouri, and Kepler Mountains, Lake Te Anau—I was interested to find a remarkable number of moths with wings shortened, at least, or semi-apterous females.

The following there found were of this nature:—

Ichneutica ceraunias Feld.
Venusia undosata Feld.
Xanthorhoe occulta Philp.
X. helias Meyr.
Notoreas villosa Philp.
Proteodes clarkei Philp.
Scoparia clavata Philp.
Gymnobathra coarctatella Walk.

Some of the new or little known species that occurred plentifully at times, locally, but have not been found previously numerous were the following:—

Ichneutica lindsayi Philp.
Porina ascendens Huds.
P. oreas Huds.
Hypenodes costistrigalis Steph.
Melanchra chryserethra Hamps.
M. asterope Huds.
M. lithias Meyr.
Selidosema terrena Philp.
Orthoclydon chlorias Meyr.
Hydriomena praerupta Philp.
Tatosoma apicipallida Prout.
Plutella megalynta Meyr.
P. psammochroa Meyr.
Proteodes clarkei Philp.
Astrogenes insignita Philp.
Glyphipteryx scintilla Clarke.
Scoparia asaleuta Meyr.
S. subita Philp.
S. fumata Philp.
S. panopla Meyr.
S. legnota Meyr.
S. *illota* Philp.
S. clavata Philp.
Harmologa sanguinea Philp.
Borkhausenia vestita Philp.
B. honorata Philp.
B. laudata Philp.
B. compsogramma Meyr.
B. robiginosa Philp.
Aletia empyrea Huds.
Chloroclystis malachita Meyr.
C. punicea Philp.
C. melochlora Meyr.
Metacrias erichrysa Huds.
Dasyuris octans Huds.
D. leucobathra Meyr.
D. hectori Butl.
D. austrina Philp.
Notoreas incompta Philp.
N. villosa Philp.
N. omichlias Meyr.
Xanthorhoe umbrosa Philp.
X. dissimilis Philp.
X. chionogramma Meyr.
X. obarata Feld.
Gelaphaula vana Philp.
Tauroscopa trapezitis Meyr.
Orthenches vinitincta Philp.
Nepticula lucida Philp.
Tinea dicharacta Meyr.
Sabatinca calliarcha Meyr.
S. chrysarcha Meyr.
Mnesarchaea acuta Philp.
Mallobathra illustris Philp.
M. perisseuta Meyr.
Taleporia aphrosticha Meyr.
T. microphanes Meyr.
T. triangularis Philp.

An interesting and beautiful scene observed by the light of the petrol lamp one night was a flight of *Tatosomas,* many hundreds strong, hovering about the blossoms of an expanse of Dracophyllums, their extraordinarily elongated and sinuous bodies and greenish-shaded wings giving them a most charming and dainty appearance as they rose and fell in the air, gracefully alighting at times on the flowers with vibrant wings, and again, with aerial evolutions appearing to resemble " falling leaves," their undulations exhibiting a most decorative and unusual effect. This was in February, on the Kepler Mountain, at about 3000 feet. Three species were abundant:—*T. lestevata* Walk., *timora* Meyr., and *tipulata* Walk. A few *T. apicipallida Prout* and one of *T. alta* Philp. were taken at the same time.

Another occurrence, of a different kind, was the rather surprising appearance of moths belonging to the Genus *Mallobathra* and its allies in the following circumstances. One morning, shortly after daybreak, at 4000 feet, at my camp on the slopes of Mount Hart, I was glancing through the doorway at the fine mist that was falling when I observed a specimen of the hitherto rarely seen moth, *M. illustris* Philp., on the wing. I expected it to be a stray specimen, but on observation I also saw one of *Taleporia aphrosticha* Meyr. flying. I captured them both, and then went out and found that several others were there, and I subsequently took good series of both these species and of others, all flying in the heavy dew of early morning. Apparently the extreme fragility of their structure has necessitated this adaptation to environment. I have taken *M. perisseuta* Meyr., *T. microphanes* Meyr., and *Scoriodyta conisalia* Meyr., and also the type specimens of *T. triangularis* Philp. at other places since then, also in the damp mists before sunrise, when other insects are usually quiescent. Some of these are common in their habitats, but on the mountains I have never seen any specimens of *T. aphrosticha, T. triangularis,* or *M. illustris* during the day time, and the others are not so plentiful at any time as in moist places at daybreak. They may, however, be taken sparingly at any time of day in the forests. These species are mostly regarded as very rare, but they are probably not often observed, although plentiful.

I have lately taken specimens of *Mallobathra nocturna* Clarke at Auckland during early mornings when the air was densely laden with moisture. The type, however, was beaten out of brushwood at Kauri Gully in the day time. *M. araneosa* Meyr. I have only captured in early mornings at Dunedin*.

RHOPALOCERA.

Argyrophenga antipodum Dbld. Plentiful on the Oreti and Mararoa Rivers and the slopes of the Takitimos.

Erebia merula Hew. Skelmorlie: Kepler Mountains. The mountain butterflies did not seem to be as plentiful in the Manapouri-Te Anau districts as they are at Wakatipu and to the north.

Vanessa gonerilla Fabr. Common on the eastern hills of the Lake Country.

Chrysophanus salustius Fabr. Hope Arm, Manapouri; Eglinton Valley and elsewhere. A plentiful species.

C. boldenarum White. Very plentiful on all the rivers and shingle beaches.

Lycaena oxleyi Feld. Not very plentiful. I am not sure whether this is the same species as the much larger Australian insect, *L. labradus* Godt, that has established itself in the north. Mararoa River, " The Wilderness," to Lake Te Anau.

ARCTIADAE.

Metacrias huttoni Butl. Common on the slopes of the Takitimo Mountains and near the Mararoa River in February.

M. strategica Huds. Oreti River, in October; a few specimens.

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* Pre-sunrise-flying species of *Mallobathra* discovered since the above was written are my *M. cataclysma* Clarke, from upper Routeburn River, and *M. memotuina* Clarke, from Anderson's Bay, Dunedin.

M. erichrysa Meyr. This beautiful moth was most abundant on the McKinnon Pass, Milford Track, at 3000 to 4000 feet, in December and January. We also took it on Mount Kemp, above the Worsley Stream, and on the Kepler Range at the west of South Arm, Lake Te Anau, and it is probably on most of the mountains of the Lake Districts.

Celama parvitis Howes. A specimen of this apparently rare moth taken among Leptospermum, S.E. of Te Anau, in December. Since my discovery of the type on the slopes of Harbour Cone, Otago Harbour, in 1915, this capture in 1928 was the first time I had again met with it.

Nyctemera annulata Boisd. Extremely common in October at the south of Te Anau, where hundreds were on the wing shortly after daybreak. The empty pupal cases were found in the greatest profusion under stones.

NOCTUIDAE.

Heliothis armigera Hubn. Common on the Takitimo Mountains and at Te Anau.

Euxoa radians Guen. A specimen netted at Lake Manapouri.

„ *admirationis* Guen. Very common in the Lake Country.

Agrotis ypsilon Rott. Also very common.

„ *spina* Gn. Closely allied to the preceding, and common.

„ *innominata* Huds. At light, Milford Sound Hotel. Common.

Graphiphora compta Walk. A few at Te Anau.

Austramathes purpurea Butl. This beautiful chocolate-brown moth was by no means rare in October on the Takitimo Mountains, and is probably found in most Lake Districts.

Andesia pessota Meyr. One netted on the lower slopes of Takitimo Mountains, in October.

Homohadena fortis Butl. McKinnon Pass. Several specimens in January.

Ichneutica ceraunias Meyr. This handsome moth was common on the McKinnon Pass, and other mountains of Te Anau, also on the Hunter Mountains, above Lake Manapouri.

I. lindsayi Philp. Captured by Mr S. Lindsay and myself in 1923 at an altitude of about 4000 feet on Flat Top Mountain, Lake Manapouri. I subsequently took a good series in 1928 at the same locality. Apparently a local species.

I. dione Huds. Hunter Mountains, Manapouri, and Kepler Mountains, Te Anau. Rare.

I. nervosa Huds. One on the Arthur River, Milford Track. A rare species also.

Leucania alopa Meyr. Fairly common.

L. purdii Fer. A beautiful moth, common on the Milford Track and elsewhere.

L. unica Walk. Common at Te Anau.

L. acontistis Meyr. A few at Te Anau.

L. sulcana Fer. Common, especially at Te Anau.

L. toroneura Meyr. Te Anau. Not common.

L. blenheimensis Fer. One on the McKinnon Pass.

L. semivittata Walk. Common at Te Anau and Manapouri.

L. phaula Meyr. Common at Te Anau.

Physetica caerulia Gn. A fine moth; its varieties range from steely-blue to yellow. It is a common mountain moth, and comes to " sugar " freely.

Aletia nullifera Walk. Common on many mountains.

A. unipuncta Haw. Fairly common.

A. griseipennis Feld. A handsome moth; very common.

A. cuneata Philp. One only, on Mount Kemp.

A. moderata Walk. Common.

A. empyrea Huds. Since my capture of the types in 1915, the ♂ at the Routeburn River and the ♀ on Ben Lomond, above Queenstown, this fine insect has seldom been captured. I took a specimen on the Minaret Peaks, Lake Wanaka, in 1925, and two fine specimens and many worn ones on Flat Top Mountain, Hunter Mountains, Lake Manapouri, in January, 1928, all at about elevations of from 3000 to 4000 feet.

A. obsecrata Meyr. A specimen on the McKinnon Pass.

A. longstaffi Howes. ·A short series. Takitimo Mountains, October.

Dipaustica epiastra Meyr. Two on McKinnon Pass.

Persectania steropastis Meyr. Only two seen of this common moth, but its food plant, Phormium tenax, showed evidences of the destructive ravages of the larva.

P. composita Guen. Very common.

P. disjungens Walk. A fairly common species at Lake Manapouri, on the McKinnon Pass, and on the Takitimo Mountains.

P. atristriga Walk. Common.

P. arotis Meyr. Several at " sugar " at Te Anau, and Takitimo Mountains.

P. propria Walk. Superficially close to P. atristriga: this moth was not common, but a few examples were taken at Te Anau, at " sugar."

Erana graminosa Walk. Te Anau. Occurred fairly commonly. A fine moth.

Melanchra plena Walk. A fairly common moth.

M. maya Huds. Another handsome moth; fairly common.

M. octans Huds. Takitimo Mountains, October. Uncommon. Attached to *Sophora tetraptera.*

M. meyricci Hamps. Skelmorlie Peak, Te Anau, several, and one on the McKinnon Pass.

M. levis Philp. Not common. At " sugar," Te Anau.

M. phricias Meyr. Fairly common.

M. asterope Huds. Rare; McKinnon Pass and Skelmorlie. Two examples in good condition. Several worn ones also.

M. chryserethra Hamps. Rather a rare moth usually; a fair series on Skelmorlie Peak.

M. praesignis Howes. One on Flat Top Mountain, Lake Manapouri.

M. lithias Meyr. A fine series of this handsome and usually rare moth was secured at light on Flat Top Mountain by Mr S. Lindsay and myself.

M. sequens Howes. One only. Te Anau.

M. tartarea Butl. Takitimo Mountains. Rare, in March.

M. coeleno Huds. Several at Te Anau.

Melanchra species, mostly uncommon, that occurred in October on the Takitimo Mountains are as follows:—*Diatmeta* Huds., *alcyone* Huds., *vitiosa* Butl., *decorata* Philp. The following were commonly taken at various localities:—*Homoscia* Meyr., *lignana* Walk., *ustistriga* Walk., *infensa* Walk., *stipata* Walk., *agorastis* Meyr., *ochthistis* Meyr., *paracausta* Meyr., *mutans* Walk., *furtiva* Philp., *dotata* Walk., *omoplaca* Meyr., *rubescens* Butl., *prionistis* Meyr., *morosa* Butl., *insignis* Walk., *beata* Howes.

Bityla defigurata Walk. Common.

Ariathisa comma Walk. Common.

Hypenodes costistrigalis Steph. With Mr S. Lindsay I took a good series of this species at a tarn, Hope Arm, Manapouri. I also found it common in the swampy country near "The Monument."

Rhapsa scotoscialis Walk. Common in most localities.

GEOMETRIDAE.

Tatosoma tipulata Walk. Fairly common; Clinton River and distributed.

T. timora Meyr. Not uncommon.

T. topia Philp. One only, at Hope Arm, Manapouri.

T. lestevata Walk. A beautiful species; fairly common.

T. agrionata Walk. The commonest species at Te Anau.

T. apicipallida Prout. Kepler Mountains, Glade House, Clinton River; a few.

T. alta Philp. McKinnon Pass; Mount Kemp, Kepler Mountains; rather scarce.

T. fasciata Philp. Rare on Flat Top Mountain, Lake Manapouri.

Elvia glaucata Walk. A beautiful moth; very common.

Microdes epicryptis Meyr. A few at Hope Arm and Clinton River.

M. quadristrigata Walk. Common in various parts of the Lake Country.

Phrissogonus laticostatus Walk. Clinton River; a few.

P. testulatus Guen. Various localities.

Chloroclystis semialbata Walk. Common.

C. rivalis Philp. McKinnon Pass. Fairly common.

C. sandycias Meyr. Common, especially on the Takitimo Mountains, in October.

C. melochlora Meyr. A fine series of this beautiful moth was netted on the McKinnon Pass.

C. lichenodes Purd. This interesting moth was common in various localities.

C. muscosata Walk. Very common.

C. punicea Philp. Mount Kemp, Skelmorlie, and McKinnon Pass. Not very common.

C. lacustris Meyr. Clinton River. Not common.

C. bilineolata Walk. Common on the Milford Track, especially at Pompolona.

C. furva Philp. Flat Top Mountain, Lake Manapouri; a few.

C. rubella Philp. Common on Flat Top Mountain, and on the Kepler Mountains, South Arm of Te Anau.

C. halianthes Meyr. Not common; two on Skelmorlie.

C. malachita Meyr. Occurs sparingly. I took several at the Quinton Huts.

C. magnimaculata Philp. Common Flat Top Mountain, Kepler Mountains, and Milford Track. The mountain form is larger and lighter in colour than Dunedin specimens.

C. fumipalpata Feld. A few on McKinnon Pass.

C. nereis Meyr. The commonest Chloroclystis on these mountains.

Eucymatoge gobiata Feld. Very common.

E. anguligera Butl. Common.

Hydriomena purpurifera Fer. A beautiful species; common usually.

H. arida Butl. Taken sparingly on the Takitimos and at the Lakes.

H. siria Meyr. A few in October on the slopes of the Takitimos.

H. deltoidata Walk. Common.

H. callichlora Butl. Fairly common, especially in October.

H. praerupta Philp. Several on the Clinton River and at the Quinton Huts.

H. hemizona Meyr. On the Kepler Mountains this moth was most plentiful.

H. subrectaria Guen. One only. Takitimo Mountains.

H. subochraria Dbld. Common at several parts.

Poecilasthena pulchraria Dbld. Common in most localities.

P. subpurpureata Walk. The commonest of the genus at the Takitimos.

P. schistaria Walk. Also common.

Euchoeca rubropunctaria Dbld. An occasional specimen was seen.

Paradetis porphyrias Meyr. Sometimes seen in numbers among ferns at sunny spots. Taken in various localities.

Venusia verriculata Feld. Usually common, but only seen in the Eglinton Valley. Probably in most other Lakes Districts.

V. undosata Feld. A rather large pale form; was most plentiful along the Clinton River, near the Quinton Huts, and along the track to the Sutherland Falls, attached to *Gaya lyalli.*

V. charidema Meyr. An occasional specimen taken among Dracophyllum.

V. xanthaspis Meyr. Arthur River. Not very plentiful.

Orthoclydon pseudostinaria Huds. Two at the Upper Clinton River.

O. praefectata Walk. Very common at a locality near Lake Manapouri.

O. chlorias Meyr. In February this beautiful moth is by no means rare on the Milford Track.

Asaphodes rufescens Butl. Very common on the outskirts of the bush.

A. megaspilata Walk. Occasionally seen.

A. parora Meyr. Rather uncommon. One at Glade House and one at the Pompolona Huts.

A. abrogata Walk. Common at the Takitimo Mountains in February.

Notoreas insignis Butl. Common in February at about 2000 feet; Takitimos.

N. villosa Philp. Kepler Mountains. Abundant at 5000 feet in late December. We did not see it on other mountains, but probably it would appear a week or two later.

N. orphnaea Meyr. Very common on Flat Top Mountain, Kepler Mountains, and the McKinnon Pass.

N. mechanitis Meyr. Common on various mountains.

N. incompta Philp. Less plentiful than N. orphnaea at the same localities.

N. anthracias Meyr. Common.

N. omichlias Meyr. Several on Flat Top Mountain and on the Kepler Mountains.

N. brephos Walk. This species and var. *zopyra* Meyr. were plentiful.

N. hexaleuca Meyr. Rather uncommon. Skelmorlie.

N. paradelpha Meyr. Plentiful.

Dasyuris hectori Butl. McKinnon Pass, Kepler Mountains, and Flat Top Mountains.

D. partheniata Guen. Common.

D. anceps Butl. Commonest on the Kepler Mountains.

D. octans Huds. Plentiful on Flat Top Mountain. Discovered by Mr S. Lindsay and myself in 1923.

D. leucobathra Meyr. Rather rare. Flat Top Mountain.

D. austrina Philp. Kepler Mountains, Flat Top Mountain. This is the small form of *D. hectori.*

Dasysternica callicrena Meyr. Flat Top Mountain. Common.

Lythria catapyrrha Butl. Plentiful along the Whitestone River and on the Takitimos.

L. regilla Philp. Flat Top Mountain. A rather uncommon species.

L. perornata Walk. Fairly common.

Leptomeris rubraria Dbld. Common along the Mararoa River and near the Lakes.

Adeixis griseata Huds. Very common near "The Monument" among the tarns and swampy country.

Dichromodes nigra Butl. Skelmorlie; several specimens.

D. gypsotis Meyr. A specimen taken on the Takitimos in October.

Epirranthis alectoraria Walk. Plentiful.

E. hemipteraria Guen. Very plentiful.

E. ustaria Walk. Plentiful.

Xanthorhoe occulta Philp. Very common on all the Lake mountains visited by me.

X. stinaria Gn. Clinton River, Pompolona, and the slopes of the McKinnon Pass.

X. bulbulata Guen. Common, in October, Oreti River and Takitimo Mountains.

X. chionogramma Meyr. A good series taken. Clinton River and slopes of McKinnon Pass.

X. cedrinodes Meyr. Not common. Takitimos, in October. South Arm, Te Anau.

X. subobscurata Walk. A few only. Skelmorlie.

X. umbrosa Philp. Particularly plentiful on Flat Top Mountain, Hunter Mountains.

X. rosearia Dbld. Common.

X. chlamydota Meyr. Clinton River; several.

X. clarata Walk. Common.

X. declarata Prout. Glade House, Clinton River. Not common.

X. cataphracta Meyr. Flat Top Mountain; common; Pompolona; a few.

X. oraria Philp. Eglinton Valley. Rather scarce.

X. aegrota Butl. Common at Te Anau.

X. helias Meyr. Common in February, Te Anau.

X. obarata Feld. Arthur River. Several taken at Quinton and near the Sutherland Falls, also at Hope Arm, Lake Manapouri, and Kepler Mountains.

X. cymozeucta Meyr. Several at Glade House, and fairly common at Hope Arm.

X. camelias Meyr. Eglinton Valley. Two specimens.

X. orophyla Meyr. Takitimo Mountains, Te Anau. Common.

X. semifissata Walk. Common in most forests.

X. stricta Philp. Not common. Taken on Flat Top Mountain, Manapouri.

X. venipunctata Walk. Common at Takitimo Mountains in March.

X. philpotti Prout. Common.

X. beata Butl. Common usually.

X. adonis Huds. Often taken on the Clinton and Arthur Rivers, and elsewhere.

X. prasinias Meyr. Common in October, Takitimos. Common on the Milford Track.

X. exoriens Prout. Common on the Takitimos in March.

X. dissimilis Philp. Netted sparingly on Flat Top Mountain.

X. limonodes Meyr. Not common. Lake Te Anau.

X. semisignata Walk. Common.

X. cinerearia Dbld. Common.

X. eupitheciaria Guen. I took this species only at S.W. Arm, Te Anau, but it is sure to be widely distributed.

X. plumbea Philp. Common. Apparently a variety of *cinerearia* Dbld.

Selidosema terrena Philp. Very plentiful on Flat Top Mountain, although not usually so anywhere else in my experience.

S. suavis Butl. Fairly plentiful.

S. pelurgata Walk. Extremely plentiful in several localities.

S. rudiata Walk. Common in October at the Takitimos.

S. indistincta Butl. This was formerly known as *melinata* Feld. A common species.

S. lupinata Feld. Te Anau. Common in March.

S. monacha Huds. Several on the Kepler Mountains and Skelmorlie.

S. leucelaea Meyr. Common at Te Anau.

S. productata Walk. Common.

S. panagrata Walk. Common.

S. dejectaria Walk. Common.

Sestra flexata Walk. Fairly common.

S. humeraria Walk. Common.

Gargaphia muriferata Walk. Good varieties of this interesting species were secured at various parts.

Azelina fortinata Guen. Very common.

A. gallaria Walk. A few at Hope Arm, Manapouri, and several at Te Anau.

A. nelsonaria Feld. In South Arm, Te Anau, I took this species sparingly, and at Hope Arm, but it is sure to be found at other localities.

Declana leptomera Walk. Takitimos and Lake; very plentiful.

D. feredayi Butl. An occasional one taken.

D. egregia Feld. A beautiful moth taken occasionally at Te Anau.

D. griseata Huds. Takitimos. Not common, but is probably more so in the early spring.

D. hermione Huds. One only; South Arm.

D. niveata Butl. Fairly common.

D. floccosa Walk. Common.

D. junctilinea Walk. An occasional specimen taken.

D. glacialis Huds. A few on the Kepler Mountains.

PSYCHIDAE.

Oeceticus omnivorus Fer. Common, but only evidenced by its cocoons. I have often bred the moth from the pupal stage at Dunedin in October; have never netted it.

Orophora unicolor Butl. Only cocoons seen occasionally. I have an imago reared from an Otago pupa in September.

TORTRICIDAE.

Carposina thalamota Meyr. A specimen taken on Flat Top Mountain.

C. adreptella Walk. Common.

C. cryodana Meyr. Takitimos and Lake; common.

C. gonosemana Meyr. Very common.

C. exochana Meyr. Common.

C. contactella Walk. Common.

Proselena niphostrota Meyr. An occasional one taken.

Pyrgotis consentiens Philp. Occurred in numbers on Flat Top Mountain.

P. pyramidias Meyr. Kepler Mountains, Flat Top Mountain, and elsewhere.

Catamacta gavisana Walk. Very common.

C. lotinana Meyr. One at Lumsden.

Capua cyclobathra Meyr. An occasional specimen.

C. plinthoglypta Meyr. One taken on the Arthur River.

C. semiferana Walk. Very common. Some forms were close to *C. intractana* Walk., an Australian species, introduced.

C. plagiatana Walk. A common species of which many varieties were taken.

Eurythecta curva Philp. One on Flat Top Mountain.

E. eremana.—Takitimos and Te Anau; common.

Epichorista emphanes Meyr. Kepler Mountains, Clinton River. common in many places.

E. persecta Meyr. Takitimos; common.

E. hemionana Meyr. Common.

E. crypsidora Meyr. Several at West Lake, Manapouri; probably common.

E. candida Clarke. I have only seen the type, which I took at Hope Arm in 1923.

Harmologa amplexana Z. Common at Te Anau.

H. scoliastis Meyr. Fairly common. Te Anau and Takitimos.

H. oblongana Walk. Takitimos; a few.

H. sanguinea Philp. Flat Top Mountain. Fairly common.

H. festiva Philp. Flat Top Mountain. A good series of this bright species.

Tortrix charactana Meyr. Common in forest.

T. melanosperma Meyr. Lake Te Anau. Fairly common.

T. tigris Philp. One only of this species at Te Anau.

T. leucaniana Walk. Common at Te Anau.

T. indomita Philp. Glade House. Not common.

T. molybditis Meyr. Common.

T. cuneata Clarke. Hope Arm, Lake Manapouri; one specimen.

T. conditana Walk. Several taken.

T. pictoriana Feld. A plentiful insect in February.

T. flavescens Butl. Common.

T. sphenias Meyr. Kepler Mountains, Arthur River. Not uncommon.

T. inusitata Philp. One at Glade House. I discovered the type at Waitati, near Dunedin, since when it has sparingly been taken in Fiordland.

T. excessana Walk. Common.

Ctenopseustis obliquana Walk. Common.

Ascerodes prochlora Meyr. Fairly plentiful; Flat Top Mountain and Kepler Mountains.

Gelophaula vana Philp. Flat Top Mountain; several.

G. trisulca Meyr. A few on the McKinnon Pass.

G. aridella Clarke. Two taken on Flat Top Mountain.

Cnephasia petrias Meyr. A very common species; Takitimos.

C. jactatana Walk. A common species.

C. sphenias Meyr. Kepler Mountains, Arthur River. Not uncommon.

C. imbriferana Meyr. Common at the Takitimos.

C. microbathra Meyr. Common among ferns.

Hendecasticha aethaliana Meyr. Uncommon; Takitimos.

Spilonota parthenia Meyr. Eglinton Valley. Locally fairly common.

S. ejectana Walk. Fairly common.

S. zopherana Meyr. Very common at Lake Te Anau among Leptospermum.

S. emplasta Meyr. A specimen of this species taken, but may be a variety of the preceding.

Crocidosema plebeiana Zell. Lake Te Anau.

Bactra noteraula Wis. Common.

Laspeyresia pomonella Linn. Lumsden. One on a shop window.

PYRALIDAE.

Sporophyla oenospora Meyr. Common; Oreti River and Takitimos.

Delogenes limodoxa Meyr. Common in February; Takitimos.

Ephestia kuehniella Zell. Several at a cottage window; Te Anau.

Diptychophora species as follows were taken at Lakes Manapouri and Te Anau:—*D. auriscriptella* Walk., *microdora* Meyr., *helioctypa* Meyr., *lepidella* Walk., *selenaea* Meyr., *epiphaea* Meyr., *interrupta* Walk., *leucoxantha* Meyr., *persophanes* Meyr., *chrysochyta* Meyr., *harmonica* Meyr., *planetopa* Meyr.

Gadira acerella Walk. Occasionally taken.

Argyria pentadactyla Zell. Fairly common on the Takitimos in February.

Tawhitia glaucophanes Meyr. Skelmorlie; a few.

T. leonina Philp. Takitimos; common.

Tauroscopa trapezitis Meyr. A fine series of varieties was secured on Flat Top Mountain.

Orocrambus catacaustus Meyr. Kepler Mountains; common.

O. melampretrus Meyr. Skelmorlie, McKinnon Pass; common.

O. machaeristes Meyr. Skelmorlie; fairly common.

O. pervius Meyr. Flat Top Mountain; a few.

Crambus corruptus Butl. Oreti River, Takitimos; common.

C. heliotes Meyr. Very common near "The Monument" Rock and in swampy places.

C. saristes Meyr. Mararoa River, Te Anau; common.

C. simplex Butl. Takitimos. Te Anau; common.

C. apselias Meyr. Two taken at Hope Arm, Te Anau.

C. ramosellus Dbld. Takitimos. Mararoa River; common.

C. angustipennis Zell. Oreti River. Two only.

C. oppositus Philp. Very plentiful on Flat Top Mountain, its most northerly habitat known.

C. siriellus Meyr. Hope Arm. Common various localities.

C. apicellus Z. Hope Arm, Worsley Stream, Clinton River; common.

C. obstructus Meyr. Oreti River, Mararoa River; common.

C. vittellus Dbld. Takitimos; common.

C. flexuosellus Dbld. Hope Arm, Milford Track; common.

C. vulgaris Butl. Common.

C. xanthogrammus Meyr. Worsley Stream, Hope Arm. On most river flats and sandy places. Some beautiful varieties were secured.

Nymphula nitens Butl. Usually sparingly distributed, this species was found in the greatest profusion around a lagoon at Te Anau. Good varieties taken.

Musotima nitidalis Walk. Clinton River and other localities; common.

M. aduncalis Feld. Hope Arm. Not very common.

Diasemia grammalis Dbld. Takitimos. A few.

Nesarcha hybrealis Walk. Found commonly.

Mecyna maorialis Feld. Hope Arm, Clinton River; common.

M. marmarina Meyr. Hope Arm and elsewhere; common.

M. notata Butl. Hope Arm, Te Anau. Fairly plentiful.

M. flavidalis Dbld. Common among shrubs and in open places.

Proteroeca comastis Meyr. Mararoa River. Not common.

Heliothela erebopis Butl. Pompolona and McKinnon Pass; plentiful.

Diplopseustis perieralis Walk. Very common.

Scoparia illota Philp. This species, which I discovered at the Wairauahiri River, Southland, in 1917, I captured again in the South Arm, Te Anau.

S. asaleuta Meyr. A plentiful species at Hope Arm, Lake Manapouri. Usually rare.

S. clavata Philp. Very plentiful on Flat Top Mountain. Usually rare.

S. famularis Philp. The type of this distinctly marked species was taken by myself at the head of South Arm, on the Kepler Mountains. Unique at present.

S. legnota Meyr. This moth I had rarely seen until I found it plentiful on the Milford Track at Pompolona and Quinton.

S. subita Philp. Very plentiful on Flat Top Mountain. Not usually common.

S. axena Meyr. Two on Flat Top Mountain. A rare moth, apparently.

S. panopla Meyr. Sparingly taken on the Kepler Mountains.

S. trapezophora Meyr. Two on Skelmorlie.

S. paltomacha Meyr., *niphospora* Meyr., *petrina* Meyr., *nomeutis* Meyr., *trivirgata* Feld., and *psammitis* Meyr. were all taken plentifully on Flat Top Mountain, the Kepler Mountains, and McKinnon Pass, on the subalpine.

S. ergatis Meyr., *encapna* Meyr., *hemicycla* Meyr., *organaea* Meyr., *steropaea* Meyr., *philerga* Meyr., *dinodes* Meyr., *galactalis* Huds., *critica* Meyr., *colpota* Meyr., *minualis* Walk., *chlamydota* Meyr., *periphanes* Meyr., *triscelis* Meyr., *ustimacula* Feld., *characta* Meyr., *chimeria* Meyr., *thyridias* Meyr., *feredayi* Knaggs, and *minusculalis* Walk. were taken on the Milford Track.

S. epicomia Meyr., *acharis* Meyr., *parmifera* Meyr., *acompa* Meyr., *animosa* Meyr., *exilis* Knaggs, *elaphra* Meyr., *autochroa* Meyr., *rotuella* Feld., *melanaegis* Meyr., *cataxesta* Meyr., *leucogramma* Meyr., *asterisca* Meyr., *cymatias* Meyr., *sabulosella* Walk., *octophora* Meyr., *fumata* Philp., *chalara* Meyr., *cyptastis* Meyr., *diptheralis* Walk., *cyameuta* Meyr., *luminatrix* Meyr., *indistinctalis* Walk., *leptalea* Meyr., and *submarginalis* Walk. were all taken in various localities, and were common.

Platyptilia falcatalis Walk. Common.

P. heliastis Meyr. Flat Top Mountain, McKinnon Pass. Not uncommon.

P. aeolodes Meyr. Common.

P. campsiptera Meyr. McKinnon Pass; rare.

Alucita monospilalis Walk. This beautiful moth was extremely abundant.

A. furcatalis Walk. Common.

A. lycosema Meyr. Common. Close to *furcatalis* Walk. I have varieties that seem to link the two species.

A. innotalis Walk. Takitimos. Not common.

Stenoptilia vigens Feld. McKinnon Pass; rare.

S. zophodactyla Dup. One at Hope Arm.

S. orites Meyr. Rather rare, on McKinnon Pass; also on the Takitimos.

S. charadrias Meyr. Skelmorlie. Not common.

THYRIDIDAE.

Morova subfasciata Walk. Common on the outskirts of mixed bushlands. Its larva was evidently common, as evidenced by the swellings caused by them in the stems of Parsonsia.

AEGERIADAE.

Trochilium tipuliforme Cler. Lumsden. A specimen.

TINEIDAE.

Apatetris melanombra Meyr. Eglinton Valley, Te Anau; rare.

Megacraspedus calamogona Meyr. Common in October. Oreti River and Takitimos.

Aristotelia paradesma Meyr. One near the Takitimos.

Thiotricha tetraphala Meyr. One at the Accommodation House at Lake Manapouri.

T. thorybodes Meyr. Takitimos in October; rare. One at the Spey River, Manapouri.

Phthorimaea operculella Zell. Two at Lumsden.

P. cheradias Meyr. Eglinton Valley. Fairly common.

P. thyraula Meyr. One only at Hope Arm, Manapouri.

Gelechia monophragma Meyr. Very plentiful in October; Lower Takitimos, Hope Arm, Milford Track.

G. parvula Philp. Several at Hope Arm.

G. lithodes Meyr. A good series on the shingle at Hope Arm, also at the Worsley Stream and on the Milford Track, and at Milford Sound.

G. schematica Meyr. Several on the Oreti River.

G. colastadesma Clarke. Flat Top Mountain, 4000 feet, in January, 1928.

Anisoplaca achyrota Meyr. Eglinton Valley. Not uncommon.

A. acrodactyla Meyr. Hope Arm, Milford Track. Common occasionally.

Donacostola notabilis Philp. I took one of this most interesting species on Flat Top Mountain at 4000 feet in 1923 and another in 1928.

Batrachedra psithyra Meyr. Very common near a small stream in mixed bush, Hope Arm.

B. eucola Meyr. Apparently uncommon. One only, Hope Arm.

B. agaura Meyr. Common. Eglinton Valley, Hope Arm.

Borkhausenia levicula Philp. Two only, at 4000 feet, Flat Top Mountain.
B. zanthomicta Meyr. Hope Arm; common.
B. honorata Philp. Hope Arm. Not common.
B. vestita Philp. Several taken by Mr S. Lindsay and myself on Flat Top Mountain.
B. robiginosa Philp. Common on the slopes of McKinnon Pass.
B. compsogramma Meyr. Milford Track.
B. apertella Walk., *oxyina* Meyr., *innotella* Walk., *nycteris* Meyr., *scholaea* Meyr., *crotala* Meyr., *pseudospretella* Staint., *basella* Walk., *perichlora* Meyr., *siderodeta* Meyr., *xanthodesma* Philp., *hoplodesma* Meyr., *armigerella* Walk., *maranta* Meyr., *melanamma* Meyr., *phegophylla* Meyr., *politis* Meyr., *pronephela* Meyr. were taken at various localities.

Leptocroca scholaea Meyr. Common in beech forests.

Schiffermuelleria orthophanes Meyr. Occurred at various localities.

Gymnobathra coarctatella Walk. Common.
G. calliploca Meyr. Particularly common in October; seen in most localities.
G. parca Butl. Fairly common.
G. philadelpha Meyr. Appears to be rare. One only, at the Worsley Stream.
G. tholodella Meyr. Exceedingly common.
G. squamea Philp. A few only on the Kepler Mountains at 4000 feet.
G. omphalota Meyr. Very common among shrubs at the edge of the bush.

Parocystola acroxantha Meyr. Oreti River. Common in October.

Izatha pereonella Walk. A beautiful insect; fairly plentiful in the forests.
I. acmonias Philp. Quinton Huts and Arthur River. Not common.
I. picarella Walk. Takitimos and Whitestone River. Occurred sparingly.
I. balanophora Meyr. Takitimos. One taken.
I. amorbas Meyr. Several taken at Hope Arm, Lake Manapouri.
I. convulsella Walk. Common among Leptospermum at Te Anau and Manapouri.

Trachypepla lichenodes Meyr. Occurred sparingly at Hope Arm and elsewhere.
T. leucoplanetis Meyr. Rather rarely taken on the Milford Track; also at Manapouri.
T. galaxias Meyr. A few at Te Anau.
T. ingenua Meyr. Common at Pompolona and on the Clinton River.
T. euryleucota Meyr. Sparingly taken at Lake Manapouri among Leptospermum.
T. metalifera Philp. Eglinton Valley and Milford Track. Not common.
T. protochlora Meyr., *anastrella* Meyr., *contritella* Walk., *aspidephora* Meyr. were all taken commonly.

Euthictis chloratma Meyr. Hope Arm; Milford Track.

Atomotricha sordida Butl. Kepler Mountains. One only. Probably common in the spring.

A. prospiciens Meyr. Milford Track and Eglinton Valley. A few.

Barea confusella Walk. Lake Te Anau. Not uncommon.

B. exarcha Meyr. An odd specimen taken at Lumsden.

Locheutis vagata Meyr. Milford Track. Not plentiful.

Proteodes carnifex Butl. Plentiful in February; all beech forests.

P. profunda Meyr. Not particularly plentiful, but taken in various Lake regions.

P. clarkei Philp. I discovered this beautiful moth in January, 1923, when on a collecting trip with Mr S. Lindsay. It is apparently local at 4000 feet on Flat Top Mountain, among native grasses. On a subsequent visit in 1929 I took it plentifully, all specimens being caught at the same place. Only one ♀ was taken, and is semi-apterous.

Oxythecta austrina Meyr. Flat Top Mountain; Kepler Mountains. Not often taken.

Nymphostola galactina Feld. Hope Arm. Not uncommon.

Lathicrossa leucocentra Meyr. Hope Arm, Clinton and Arthur Rivers.

Cryptolechia compsotypa Meyr. An odd specimen at Hope Arm.

C. liochroa Meyr. Not uncommon. Milford Track.

C. apocrypta Meyr. Very common.

Eutorna symmorpha Meyr. A number were taken on a stream at Hope Arm.

E. caryochroa Meyr. Not uncommon.

Agriophara coricopa Meyr. Milford Track. Not very common.

Phycomorpha metachrysa Meyr. One at Lake Manapouri, also several at Eglinton River.

Thylacosceles acridomima Meyr. Very common.

Stathmopoda skelloni Butl. Very common.

S. campylocha Meyr. Not common. Two on the Arthur River.

S. phlegyra Meyr. Hope Arm. A few.

S. mysteriastis Meyr. Several on the Milford Track.

S. aposema Meyr. Common in October, Takitimo Mountains.

Zapyrastra calliphana Meyr. Common at outskirts of forests.

Batrachedra psathyra Meyr. A few taken at Hope Arm and on the Milford Track.

B. agaura Meyr. Common Hope Arm.

B. eucola Meyr. One only was taken by myself at Hope Arm.

Heliostibes insignis Philp. An interesting new species discovered by myself at 4000 feet on Flat Top Mountain, Manapouri. One specimen only.

H. electrica Meyr. Hope Arm. Not uncommon.

H. callispora Meyr. One at the Takitimo Mountains.

H. illita Feld. Very common at Hope Arm and on the Milford Track.

H atychioides Butl. Very common among Leptospermum in various places.

Charixena iridoxa Meyr. A most beautiful insect. Milford Track, McKinnon Pass, Kepler Mountains, and at Lake Manapouri. No moths were taken, the distinctive ravages of the larva on the *Astelia* leaves being the only trace of it apparent. I reared the larva and bred several examples in the following August, 1930, its early emergence explaining its apparent rarity.

Simaethis inspoliata Philp. The only specimen known at present was taken by myself on Flat Top Mountain at 4000 feet on December 27, 1928.

S. exocha Meyr. Rather uncommon on the McKinnon Pass.

S. combinatana Walk. Fairly common in October, Takitimo Mountains. Also taken at Te Anau.

S. microlitha Meyr. Common, especially in October, on the Takitimos.

S. colpota Meyr. Two at Hope Arm.

S. barbigera Meyr. Fairly common at Hope Arm, Flat Top Mountain, and the slopes of McKinnon Pass.

S. antigrapha Meyr. Milford Track. A few.

S. albifasciata Philp. One at Flat Top Mountain.

Choreutis bjerkandrella Thunb. Takitimo Mountains; common.

Glyphipteryx achlyoessa Meyr. Very common.

G. aenea Philp. Two taken on Flat Top Mountain.

G. transversella Walk. Common at Hope Arm and on the Milford Track.

G. zelota Meyr. Common on the McKinnon Pass.

G. cionophora Meyr. Common on the Takitimos and along the Oreti River in October.

G. rugata Meyr. Common at Lumsden in February.

G. bactrias Meyr. Common in October at the Takitimos.

G. scintilla Clarke. Flat Top Mountain in January. I discovered this prettily marked species at 4000 feet, its only known locality; common.

G. aulogramma Meyr. A few near the Mararoa River.

G. oxymachaera Meyr. Very common in the Lake country.

G. iocheaera Meyr. Very common also.

G. leptosema Meyr. A few taken on the Milford Track and elsewhere.

G. dichorda Meyr. Plentiful at Hope Arm, Manapouri.

G. acronoma Meyr. Mararoa River and Lake districts.

G. triselena Meyr. Fairly plentiful in several places.

Elachista ombrodoca Meyr. Very common.

E. archaeonoma Meyr. Also common.

E. gerasmia Meyr. A few on the Takitimos.

Scythris epistrota Meyr. Not uncommon on the Takitimos.

Zelleria copidota Meyr. A few in several places.

Acrocercops zorionella Huds. A specimen taken on the Clinton River.

Parectopa aellomacha Meyr. Hope Arm, South Arm, and Milford Track. Not rare.

P. panacivagans Watt. Milford Track. Attached to *Pseudopanax* foliage.

P. aethalota Meyr. Clinton River. Only one taken.

Gracilaria linearis Butl. Very plentiful.

G. selenitis Meyr. Sometimes occurring in the greatest profusion at about 3500 feet on the mountain beech, *Nothofagus*.

G. elaeas Meyr. Not uncommon.

Dolichernis chloroleuca Meyr. Occasionally taken on the Milford Track.

Protosynaema steropucha Meyr. Commonest in October at the Takitimos.

Phylacodes cauta Meyr. Not usually common. Occurred near the Oreti River.

Bedellia psamminella Meyr. Common, on *Convolvulus*, Hope Arm.

Orthenches drosochalca Meyr. A pretty species, fairly common, at Lake level.

O. porphyritis Meyr. Very common in most localities among mixed bush.

O. vinitincta Philp. Not uncommon, Clinton River.

Plutella megalynta Meyr. A good series of this mountain insect was secured on the McKinnon Pass at 3500 feet. It was commonly found in the early morning floating on the water of the tarns.

P. maculipennis Curt. Several seen at Lumsden only.

Circoxena ditrocha Meyr. One only in the S.W. Arm, Te Anau. This was a surprise, as I had previously taken it only at Auckland.

Erechthias acrodina Meyr. Not uncommon, Takitimos and Lakes.

E. charadrota Meyr. Also plentiful.

E. fulguritella Walk. Several taken at various places. A plentiful species.

Dryadaula myrrhina Meyr. Not common; Takitimos, in October.

D. castanea Philp. One of this apparently rare species taken at Hope Arm.

Eschatotypa melichrysa Meyr. Very common on the outskirts of the bush.

E. derogatella Walk. Usually occurs with the former species; common.

Nepticula lucida Philp. Since I discovered this species in 1916 I have found it plentiful in beech forest, especially at about 3000 feet. All Lake districts.

N. oriastra Meyr. Not uncommon, but rarely taken, as it has to be searched for close to the ground among daisies and grasses.

N. erichtitus Watt. One at the Takitimos.

N. tricentra Meyr. Common among mixed bush; Takitimos and Eglinton Valley.

N. cypracma Meyr. One specimen of what seems to be this species at Hope Arm.

Endophthora omogramma Meyr. Clinton River and South Arm. Not uncommon.

Crypsitricha pharotoma Meyr. Two only, at Hope Arm.
C. stereota Meyr. Common in various localities.
C. roseata Meyr. Rare; Clinton River.
C. generosa Philp. The only one known. The type was taken by Mr S. Lindsay when we were collecting at Hope Arm in 1923.
C. mesotypa Meyr. The commonest species of the genus at the Lakes.

Archyala terranea Butl. Very common at the Takitimos, and seen at Te Anau.
A. pentazyga Meyr. One only at the Eglinton River.

Sagephora jocularis Philp. One at Hope Arm.
S. phortegella Meyr. Very common in mixed bush.
S. exsangius Philp. Hope Arm. Not very common.

Monopis ethelella Newm. Very common.
M. ornithias Meyr. Commonest in October; Takitimos.

Tineola biselliella Hum. Only seen at Lumsden.
Tinea argodelta Meyr. One at Hope Arm.
T. cymodoce Meyr. Clinton River; uncommon.
T. mysticopa Meyr. Common.
T. mochlota Meyr. Occasionally taken. It was not uncommon at the Takitimos.
T. astraea Meyr. One only at Hope Arm.
T. dicharacta Meyr. Common at the Waiau River.
T. fuscipunctella Haw. Taken at Manapouri on a window.

Trichophaga tapetiella Linn. Lumsden; two specimens.

Proterodesma mysticopa Meyr. Common.

Astrogenes insignita Philp. A few in the Eglinton Valley, and one at Clinton River.

Lysiphragma epixyla Meyr. Common in mixed bush.
L. howesii Quail. Clinton River. One only.

Taleporia microphanes Meyr. Flat Top Mountain, Hunter Mountains, Kepler Mountains, and McKinnon Pass.
T. triangularis Philp. Not common. Taken with the preceding species.
T. aphrosticha Meyr. This interesting and delicate moth was not uncommon on the Kepler Mountains and on Flat Top Mountain.

Mallobathra araneosa Meyr. One on Flat Top Mountain.
M. illustris Philp. Flat Top Mountain, McKinnon Pass, and Skelmorlie. Not very plentiful.
M. homalopa Meyr. Common at Hope Arm and on the Milford Track.
M. perisseuta Meyr. A few at the Takitimos in October. Others seen at Hope Arm.

Scoriodyta conisalia Meyr. Lumsden and Mararoa River in October; common.

MICROPTERYGIDAE.

Mnesarchaea paracosma Meyr. Very common; Takitimos and Lake; October.

M. acuta Philp. A series taken on the McKinnon Pass, Upper Arthur River.

Sabatinca quadrijuga Meyr. Common in October; Takitimos and Oreti River.

S. calliarcha Meyr. Not uncommon; S.W. Arm, Milford Track, and elsewhere.

S. chrysargyra Meyr. McKinnon Pass and Milford Track; in December.

S. caustica Meyr. Takitimos, in October. A few.

HEPIALIDAE.

Porina dinodes Meyr. Common in February; Lake Te Anau.

P. jocosa Meyr. One on McKinnon Pass in February.

P. cervinata Walk. Common.

P. oreas Huds. I took several of this moth on Flat Top Mountain in January.

P. fusca Philp. A few on McKinnon Pass and Kepler Mountains.

P. ascendens Huds. This species was abundant on Flat Top Mountain. It was only known previously from Mount Arthur, Nelson.

P. despecta Walk. Very common.

Otoliths of Fishes from the Tertiary Formations of New Zealand.

By G. ALLAN FROST, F.L.S., F.G.S.

[*Read by J. Marwick before the Wellington Philosophical Society, 14th October, 1931; received by the Editor, 27th November, 1931; issued separately, 28th February, 1933.*]

THROUGH the courtesy of Dr. J. Marwick, of the Geological Survey Office, Wellington, New Zealand, I have received for description a remarkable series of fossil otoliths from various localities in New Zealand which, although their stratigraphical value may be of slight extent, are palaeontologically of great interest.

With the exception of three, the 25 species figured are all new forms, distinct from any yet described. The type examples are clear cut and in excellent preservation, and in some cases show a striking likeness to the otoliths of present-day New Zealand fishes.

It is desirable when describing fossil otoliths to compare them, if possible, with those of recent fishes, and not to rely on the determinations of previous authors, which are in some instances inaccurate. This has been done with the present examples, and all have been carefully compared with recent forms in the author's collection.

Among the deep-sea forms described there are 13 species of scopelid otoliths—four belong to the Macruridae and one is referred to the family Gadidae. Of the remainder, three belong to the family Congridae, one to the Pleuronectidae, two are from percoids, and there is one example from a species of the order Scleroparei.

The majority are from the Tutamoe Survey District; of these, 11 are from the Tutamoe Beds, Island Creek, and 11 from the Ihungia Beds, four species occurring in both places. Two are from Waingake, Patutahi Survey District, three from Waingaromia Survey District. Of the latter, one occurs also in the Tutamoe Beds and one in the Ihungia Beds. One comes from the Otapiri grey marls, one from the marl of Terakohe, Takaka, and three from the Mimi Survey District, one of these also appearing in the Tutamoe Beds.

Order INIOMI, fam. MYCTOPHIDAE.

Otolithus (Scopelus) marwicki sp. n. (Figs. 1-3, inner side; Figs. 2-4, outer side).

Description: Dimensions 4 mm. × 3 mm. Shape ovate, outer side convex, with vertical groove from the dorsal rim ending above the ventral rim; inner side flat, rostrum and antirostrum present, dorsal rim domed, with posterior part lower than the anterior, ventral rim slightly serrated. Sulcus bold, divided, cauda rectangular with groove below.

Material: Three examples, including Holotype.

Distribution: Loc. 1358, Ihungia Mudstone, Haupatua Stream; and Loc. 1349, Ihungia Beds, N.W. tributary Konganaru Stream, Tutamoe Survey District (type).

Age: Hutchinsonian, Upper Oligocene.

Remarks: This species is remarkable for the vertical groove of the outer side, resembling in this feature a scopeloid otolith described by Bassoli (1906 XII, p. 50, Pl. II, Fig. 24) *O. (Berycidarum) sulcatus* Bass. from the Miocene of Monte Gibio, Italy.

Otolithus (Scopelus) mammatus sp. n. (Fig. 5, inner side; Fig. 6, outer side).

Description: Dimensions 3½ mm. × 2¾ mm. Shape ovate, outer side convex, umbonated, groove above rostrum; inner side flat, dorsal rim domed anteriorly, ventral rim slightly serrated, rostrum stout, no antirostrum. Sulcus with upper and lower angles, cauda circular.

Material: Two examples, including Holotype.

Distribution: Loc. 1262, Island Creek (Tutamoe Beds); Loc. 1349, Ihungia Beds, tributary Konganaru Stream, Tutamoe Survey District (type).

Age: Awamoan, Lower Miocene; Hutchinsonian, Upper Oligocene.

Remarks: The general shape resembles that of *O. (Scopelus) tuberculatus* Bassoli (1906 XII, Pl. 11, Fig. 25-26) from the Miocene and Pliocene of Italy. It differs, however, in the circular cauda.

Otolithus (Scopelus) excisus sp. n. (Fig. 7, inner side; Fig. 8, outer side).

Description: Dimensions 4½ mm. × 3½ mm. Shape ovate, outer side slightly convex, furrowed on dorsal and ventral rims; inner side very flat. Dorsal rim low with posterior angle; rostrum, antirostrum, and concave excisura present. Sulcus horizontal, long, cauda oblong.

Material: Four examples, including Holotype.

Distribution: Loc. 1372, Section A, Block 13, Waingaromia Survey District (type); Loc. 1349, Ihungia Mudstone, tributary Konganaru Stream, 300-500 feet, below top.

Age: Hutchinsonian, Upper Oligocene.

Remarks: This species is noticeable for the flatness of the inner side, and for the large excisura.

Otolithus (Scopelus) tutamoensis sp. n. (Fig. 9, inner side; Fig. 10, outer side).

Description: Dimensions 4 mm. × 3 mm. The shape resembles that of *O. (Scopelus) marwicki,* it differs in the truncation of the dorsal area, and in the outer side.

Material: Six examples, including Holotype.

Distribution: Loc. 1301, Ihungia Mudstone, N.W. tributary Konganaru Stream (type); Loc. 1358, Ihungia Mudstone, Haupatua Stream, Tutamoe Survey District.

Age: Hutchinsonian, Upper Oligocene.

Otolithus (Scopelus) circularis Frost (Fig. 11, inner side; Fig. 12, outer side).

1924. Frost, *Trans. N.Z. Inst.*, vol. 55, p. 608, Pl. 61, Fig. 2.

Description: Dimensions 3 mm. × 3 mm. A circular flat form described by the author from the Awamoan Beds of Target Gully.

Material: Four examples.

Distribution: Loc. 1358, Ihungia Mudstone, Haupatua Stream, Tutamoe Survey District. Target Gully, Oamaru (type).

Age: Hutchinsonian, Upper Oligocene; and Awamoan, Miocene.

Remarks: The example figured is a much finer specimen than the original Holotype, especially in the clearer lines of the sulcus.

Otolithus (Scopelus) concentricus sp. n. (Fig. 13, inner side; Fig. 14, outer side).

Description: Dimensions 2 mm. × 2 mm. Shape circular, outer side raised and showing lines of growth, inner side flat, rostrum, antirostrum, and excisura present. Angle between dorsal and posterior rims, ventral rim strongly dentated. Sulcus typically scopelid, with double lines below the cauda.

Material: Nine examples, including Holotype.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek (eight examples) (type); Loc. 1358, Ihungia Mudstone, Haupatua Stream, Tutamoe Survey District.

Age: Awamoan, Lower Miocene; Hutchinsonian, Upper Oligocene.

Otolithus (Scopelus) regularis sp. n. (Fig. 15, inner side; Fig. 16, outer side).

Description: Dimensions 2½ mm. × 2¼ mm. Shape circular, outer side convex, furrowed on dorsal and ventral rims; inner side flat, angle between dorsal and posterior rims, rostrum broad, no antirostrum or excisura. Sulcus with angle of lower margin, ostium and cauda equal in length, cauda wider than ostium.

Material: The unique Holotype.

Distribution: Loc. 1372, Section A, Block 13, Waingaromia Survery District.

Age: Hutchinsonian, Upper Oligocene.

Remarks: Resembles the otolith of the recent species *Myctophum caninianus* (see Frost, 1926, XVIII, p. 468, Pl. XX, Fig. 13).

Otolithus (Scopelus) cassidiformis sp. n. (Fig. 17, inner side; Fig. 18, outer side).

Description: Dimensions 2¼ mm. × 2¼ mm. Shape circular, outer side convex, smooth, inner side flat; dorsal rim high anteriorly, with posterior angle, ventral rim curved and serrated, posterior rim curved, anterior rim oblique, rostrum and slight antirostrum present, no excisura. Sulcus with lower angle, ostium wide, with straight front, cauda narrow, ovate, lower margin with double lines.

Material: The unique Holotype.

Distribution: Loc. 1349, Ihungia Beds, tributary Konganaru Stream, Tutamoe Survey District.

Age: Hutchinsonian, Upper Oligocene.

Otolithus (Scopelus) konganaruensis sp. n. (Fig. 19, inner side).

Description: Dimensions 5 mm. × 4½ mm. Shape circular, outer side convex, smooth, inner side very convex, angle between dorsal and posterior rims, ventral rim serrated. Rostrum, antirostrum, and an angular excisura present. Sulcus very wide, straight, division ill-defined.

Material: Two examples, including Holotype.

Distribution: Loc. 1301, Ihungia Mudstone, tributary to Konganaru Stream, 300 to 500 feet below top, Tutamoe Survey District.

Age: Hutchinsonian, Upper Oligocene.

Otolithus (Scopelus) incisus sp. n. (Fig. 20, outer side).

Description: Dimensions 5 mm. × 4 mm. Shape ovate, umbonated and furrowed on all rims. Prominent rostrum and small pointed antirostrum, with deep short groove below it.

Material: The unique Holotype.

Distribution: Loc. 1351, three-quarters of a mile above Waingaki, Patutahi Survey District.

Age: Awamoan, Lower Miocene.

Remarks: Owing to this example being imbedded in the matrix, it is only possible to describe the features of the outer side. It differs from the remainder of the scopelid otoliths described in shape, and in the presence of the deep slit below the antirostrum.

Otolithus (Scopelus) laminatus sp. n. (Fig. 21, inner side; Fig. 22, outer side).

Description: Dimensions 3½ mm. × 3 mm. Shape circular, without rostrum, antirostrum, or excisura. Both sides flat, outer side furrowed, anterior part of ventral rim serrated. Sulcus wide, nearly straight, divided, extending entirely across the inner side, ostium longer than cauda.

Material: The unique Holotype.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District.

Age: Awamoan, Lower Miocene.

PLATE 21.

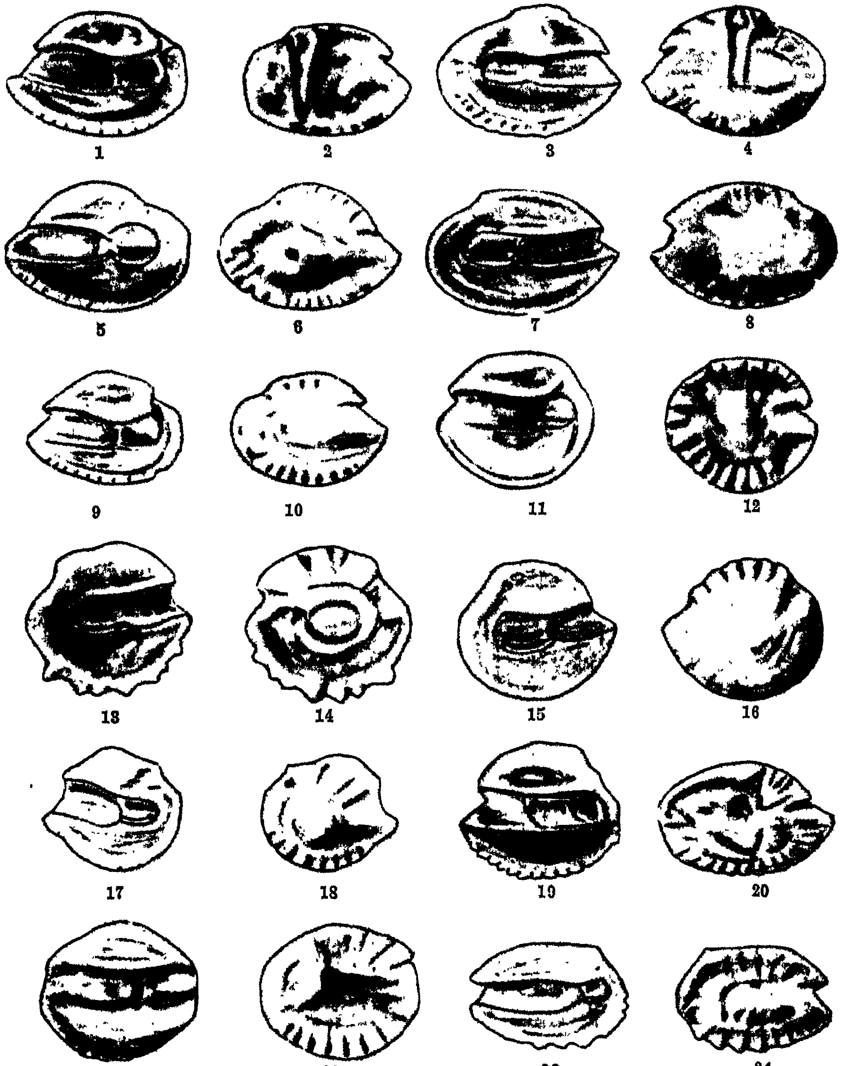
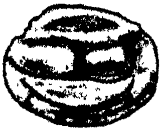


Fig. 1-4.—*Otolithus (Scopelus) marwicki* sp. n.
Fig. 5-6.—*Otolithus (Scopelus) mammatus* sp. n.
Fig. 7-8.—*Otolithus (Scopelus) excisus* sp. n.
Fig. 9-10.—*Otolithus (Scopelus) tutamoensis* sp. n.
Fig. 11-12.—*Otolithus (Scopelus) circularis* Frost.
Fig. 13-14.—*Otolithus (Scopelus) concentricus* sp. n.
Fig. 15-16.—*Otolithus (Scopelus) regularis* sp. n.
Fig. 17-18.—*Otolithus (Scopelus) cassidiformis* sp. n.
Fig. 19.—*Otolithus (Scopelus) konganaruensis* sp. n.
Fig. 20.—*Otolithus (Scopelus) incisus* sp. n.
Fig. 21-22.—*Otolithus (Scopelus) laminatus* sp. n.
Fig. 23-24.—*Otolithus (Scopelus) mimiensis* sp. n.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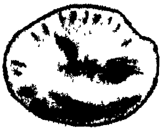
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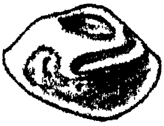
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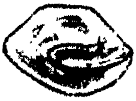
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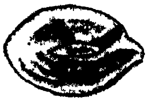
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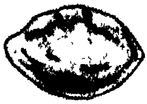
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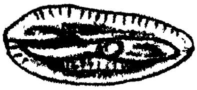
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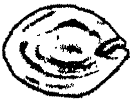
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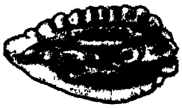
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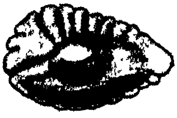
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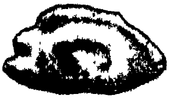
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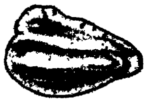
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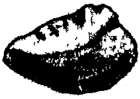
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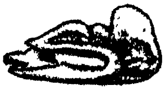
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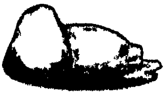
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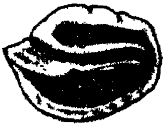
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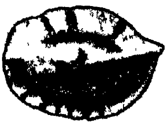
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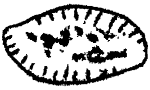
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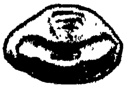
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FIG. 25-26.—*Otolithus (Scopelus) ellipticus* sp. n.
FIG. 27.—*Otolithus (Congridarum) carinatus* sp. n.
FIG. 28.—*Otolithus (Congridarum) otapiriensis* sp. n.
FIG. 29-30.—*Otolithus (Congridarum) mysticus* sp. n.
FIG. 31.—*Otolithus (Macruronus) pukeuriensis* Frost.
FIG. 32.—*Otolithus (Pleuronectidarum) orbicularis* sp. n.
FIG. 33-34.—*Otolithus (Macrurus) sagittiformis* sp. n.
FIG. 35-36.—*Otolithus (Macruridarum) latisulcatus* sp. n.
FIG. 37-38.—*Otolithus (Macrurus) toulai* Schubert.
FIG. 39-40.—*Otolithus (Physiculus) terakohensis* sp. n.
FIG. 41-42.—*Otolithus (Sparidarum) sigmoidalis* sp. n.
FIG. 43-44.—*Otolithus (Serranidarum) serratus* sp. n.
FIG. 45-46.—*Otolithus (Cyclopterus) trifoliatus* sp. n.

Otolithus (Scopelus) mimiensis sp. n. (Fig. 23, inner side; Fig. 24, outer side).

Description: Dimensions 3 mm. × 2 mm. Shape ovate, outer side convex, furrowed, inner side flat. Dorsal rim low, forming angle with the posterior rim, ventral rim strongly serrated, rostrum and antirostrum prominent and equal, excisura large. Sulcus straight, divided, ostium long, constricted anteriorly, distended medianly, cauda short and narrower than the ostium.

Material: The unique Holotype.

Distribution: Loc. 1125, coast between Waikiekie Stream and Mangapuketea Stream, Mimi Survey District.

Age: Taranakian, Upper Miocene.

Otolithus (Scopelus) ellipticus sp. n. (Fig. 25, inner side; Fig. 26, outer side).

Description: Dimensions 3 mm. × 2½ mm. Shape elliptical, both sides flat, a slight angle between dorsal and posterior rims, ventral rim curved, passing into the rounded anterior rim, which is indented above the sulcus. The sulcus is wide and straight, and has a ridge above it, the ostium is constricted anteriorly, and the cauda is large and rectangular.

Material: The unique Holotype.

Distribution: Loc. 1351, three-quarters of a mile above Waingake, Kauwaewaka Stream, Patutahi Survey District.

Age: Awamoan, Lower Miocene.

Order Apodes.

Otolithus (Congridarum) carinatus sp. n. (Fig. 27, inner side).

Description: Dimensions 3 mm. × 2½ mm. Shape irregular, biconvex, dorsal rim high, pointed, sloping forward; ventral rim deepest anteriorly, posterior rim pointed, anterior rim rounded. Sulcus oblique, with groove opening on dorsal rim.

Material: The unique Holotype.

Distribution: Loc. 1236, Ihungia Beds, Muddy Creek, Tutamoe Survey District.

Age: Hutchinsonian, Upper Oligocene.

Remarks: Resembles in shape that of the recent species *Congromureana balaerica,* and in the sulcus that of *Uroconger lepturus* (Richardson) (Frost, 1926, XVII, Pl. 11, Figs. 15-11).

Otolithus (Congridarum) otapiriensis sp. n. (Fig. 4, inner side).

Description: Dimensions 7 mm. × 5 mm. Shape ovate, biconvex, dorsal rim straight, ventral rim deepest anteriorly, posterior rim pointed, anterior rim consists of stout rostrum. Sulcus wide, open between dorsal rim and point of rostrum, end rounded.

Material: Three examples, including Holotype.

Distribution: Loc. 256, Grey marls, Otapiri Creek, Southland.

Age: Hutchinsonian, Upper Oligocene.

Remarks: Resembles that of the recent species *Uroconger lepturus* (Rich.) (Frost, 1926, XVII, Pl. 11, Fig. 15-11). It differs in the less symmetrical shape, and in the width of the sulcus.

Otolithus (Congridarum) mysticus sp. n. (Fig. 29, inner side; Fig. 30, outer side).

Description: Dimensions 3 mm. × 2 mm. Shape ovate, biconvex, symmetrical. Sulcus filled in with colliculum, a slight depression leads to dorsal and anterior rims.

Material: The unique Holotype.

Distribution: Loc. 1272, Ihungia Beds, Island Creek, Tutamoe Survey District.

Age: Hutchinsonian, Upper Oligocene.

Order ANACANTHINI.

Otolithus (Macruronus) pukeuriensis Frost (Fig. 31).

1924. *O. (Merluccius) pukeuriensis* Frost, *Trans. N.Z. Inst.*, vol. 55, p. 609, Pl. 61, Fig. 7.

Description: Dimensions 7 mm. × 3 mm.

Material: Two examples.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District; Loc. 1125, coast, Mimi Survey District; Oamaru series, Pukeuri.

Age: Awamoan, Lower Miocene; Taranakian, Upper Miocene.

Remarks: An example from Pukeuri was described by the author in 1924, and was referred to the genus *Merluccius*, but a later comparison shows that it resembles more closely the otolith of the recent species *Macruronus novae-zeelandiae* (see Frost, 1926, XVIII, 484, Pl. XXII, Fig 4-5), the anterior point being considerably higher than in *Merluccius*.

Otolithus (Macrurus) sagittiformis sp. n. (Fig. 33, inner side; Fig. 34, outer side).

Description: Dimensions 3 mm. × 2 mm. Shape that of an arrow head, outer side straight, furrowed, with a medianly placed umbo, from which a deep groove descends to the anterior rim. Anterior of otolith broad, posterior part pointed. Inner side flat, dorsal rim furrowed and serrated, a smooth surface is present above and below the sulcus. The sulcus extends across the inner side, lower margin with angle, ostium upwardly inclined, cauda curved, ending on ventral rim below the posterior point of the otolith; a small round colliculum is present in both the ostium and the cauda.

Material: Two examples, including Holotype.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District; Loc. 1293, Akiripuraho Stream, Waingaromia Survey District (type).

Age: Awamoan, Lower Miocene; Hutchinsonian, Upper Oligocene.

Remarks: Resembles the otolith of the recent species *Macrurus cœlorhynchus* (see Frost, 1926, XVIII, 483, Pl. XXII, Fig. 3).

Otolithus (Macruridarum) latisulcatus sp. n. (Fig. 35, inner side; Fig. 36, outer side).

Description: Dimensions 4 mm. × 2 mm. Shape ovate, biconvex, anterior part high, posterior part pointed; anterior rim oblique, with two rounded projections. Sulcus enclosed, wide, with median upper angle, both ends rounded.

Material: The unique Holotype.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District.

Age: Awamoan, Lower Miocene.

Remarks: The shape is similar to those of the family Gadidae, but the sulcus resembles closely that of the recent species *Trachyrhynchus trachyrhynchus* of the family Macruridae (Frost, 1926, XVIII, Pl. 12, Fig. 1).

Otolithus (Macrurus) toulai Schubert (Fig. 37, inner side; Fig. 38, outer side).

E. Schubert, 1905, 55, Pl. XVI, Fig. 34-37.
G. G. Bassoli, 1906, XII, Pl. 1, Fig. 13-14.
G. Allan Frost, 1924, 55, p. 608, Pl. 61, Fig. 4.

Material: One example (young), 2¼ mm. × 1½ mm.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District.

Age: Awamoan, Lower Miocene.

Remarks: Described by Schubert from the tertiaries of Austro-Hungary, by Bassoli from the Miocene of Monte Gibio, Italy, and by the author from Pukeuri, Awamoa, Ardgowan, and Target Gully, New Zealand.

Otolithus (Physiculus) terakohensis sp. n. (Fig. 39, inner side; Fig. 40, outer side).

Description: Dimensions 2¼ mm. × 1½ mm. Shape irregular, outer side bulbous, anterior part raised, inner side flat; anterior part of dorsal rim high and rounded, ventral rim with three processes. Sulcus situated posteriorly to the dorsal elevation, contains angle on lower margin, ostium oval, cauda distended and open on posterior rim.

Material: The unique Holotype.

Distribution: Loc. 1286, marl, Terakohe, Takaka.

Age: Hutchinsonian, Upper Oligocene.

Remarks: This otolith resembles that of the recent New Zealand species *Physiculus bacchus* (see Frost, 1926, XVIII, p. 488, Pl. XXII, Fig. 24) in the high dorsal projection and in the furcation of the posterior rim. It differs in the absence of similar processes anteriorly, also in the fore part of the sulcus. It resembles more closely the fossil form *O. (Physiculus) bicaudatus* Frost (1924, *Trans. N.Z. Inst.*, 55, p. 608, Pl. 61, Fig. 5), described by the author from Pukeuri, New Zealand, but differs in the shape of the dorsal process, and in the sulcus.

Order HETEROSOMATA.

Otolithus (Pleuronectidarum) orbicularis sp. n. (Fig. 32, inner side).

Description: Dimensions 4 mm. x 3½ mm. Shape subcircular, biconvex; outer side smooth, inner side smooth, showing rings of growth. Sulcus open on anterior rim, ostium small, cauda not discernible.

Material: The unique Holotype.

Distribution: Loc. 1125, coast between Waikiekie Stream and Mangapuketa Stream, Mimi Survey District.

Age: Taranakian, Upper Miocene.

Remarks: Resembles the otolith of the recent species *Peltorhamphus novae-zeelandiae* (see Frost, 1930, vol. V, p. 234, Pl. IX, Fig. 12).

Order PERCOMORPHI.

Otolithus (Sparidarum) sigmoidalis sp. n. (Fig. 41, inner side; Fig. 42, outer side).

Description: Dimensions 3 mm. × 2½ mm. Shape ovate, outer side convex, furrowed on dorsal and ventral rims, inner side flat, with depression above sulcus. Dorsal rim highest anteriorly, posterior rim forms small angles with dorsal and ventral rims; a small pointed rostrum is present. Sulcus sigmoidal, direction horizontal, two angles on lower margin; ostium upwardly inclined, cauda longer than ostium.

Material: Two examples, including Holotype.

Distribution: Loc. 1236, Ihungia Beds, Muddy Creek; Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District (type).

Age: Hutchinsonian, Upper Oligocene; Awamoan, Lower Miocene.

Remarks: This otolith resembles that of the recent berycoid species *Polymixia japonica* (see Frost, 1927, XIX, p. 440, Pl. VIII, Fig. 1), but differs in the upward inclination of the cauda, resembling in this respect that of the percoid species *Micropterus salmonoides* (see Frost, 1927, XX, p. 301, Pl. V, Fig. 19). The general characteristics appear to agree best with the otoliths of the family Sparidae, notably with those of *Cantharus lineatus* (see Frost, 1927, XX, p. 301, Pl. V, Fig. 17); it appears to be an early sparid form with berycoid affinities.

Otolithus (Serranidarum) serratus sp. n. (Fig. 43, inner side; Fig. 44, outer side).

Description: Dimensions 6 mm. × 3 mm. Shape long, ovate, outer side flat, furrowed on the dorsal and ventral rims, inner side flat. Dorsal rim curved and serrated, ventral rim deepest anteriorly, serrated, forms angle with posterior rim, anterior rim consists of broad. rostrum. Sulcus straight, angle present on lower margin; ostium open on upper part of rostrum, cauda narrow, with curved and pointed end.

Material: The unique Holotype.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District.

Age: Awamoan, Lower Miocene.

Remarks: This species resembles in outline the otoliths of the recent species *Centropomus undecimalis*, it differs in the flatness of its form, and in the regular dorsal rim. The sulcus resembles those of the recent percoid fishes *Pomatomus saltatrix* and *Arripis georgianus* (see Frost, 1927, vol. XX, Pl. V, Figs. 5, 6, 7).

Order SCLEROPAREI.

Otolithus (Cyclopterus) trifoliatus sp. n. (Fig. 45, inner side; Fig. 46, outer side).

Description: Dimensions 2 mm. × 1½ mm. Shape subcircular, biconvex, outer side smooth, inner side with conchoidal depression above the sulcus. Sulcus biovate, enclosed and divided; ostium and cauda equal, in conjunction with the depression of the dorsal area they form a trefoil.

Material: The unique Holotype.

Distribution: Loc. 1262, Tutamoe Beds, Island Creek, Tutamoe Survey District.

Age: Awamoan, Lower Miocene.

Remarks: Resembles in all features the otolith of a young example of the recent species *Cyclopterus lumpus* (see Frost, 1929, vol. IV, p. 262, Pl. 111, Fig. 27).

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—— 1930. *Ann. and Mag. Nat. Hist.*, Series 10, V, p. 231-239.

A Case of Mass-Occurrence of Non-Inherited Chlorophyll Defects in Wheat.

By Dr. O. H. Frankel, N.Z. Wheat Research Institute.

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In contrast to the other cereals, chlorophyll defects in wheat are exceedingly rare. The only case, to the writer's knowledge, communicated so far showed a trifactorially inherited albino (Smith and Harrington, 1929). Stadler (1930) remarked upon the difficulty of tracing recessive mutants in polyploid species, owing to their gene reduplication. Plasmatic inheritance of chlorophyll defects, as found in barley and rice, has not been reported in wheat.

In consequence some interest attached to the appearance of a comparatively large number of variegated wheat plants in the early spring of 1930. The affected plants were found in a collection of foreign varieties from various parts of the world. All except three variants were found in single-plant progenies, one (or, in two cases, two) variegated plants appearing in plots of 25 plants each. The seed of most of the lines containing defectives was obtained in 1929 and grown in the same year, the 1930 crop therefore being derived from seed raised in New Zealand. The varieties Marquis 10B and Victor, however, had been imported several years previously. Sowing took place from May 28 to June 4.

The chlorophyll defects consisted in a distinct striping of the leaves, showing all gradations between a single narrow white line with the rest of the leaf green, and the opposite distribution. The stripes were clearly distinct, similar to those described for maize and barley, and were visible up to the dying off of the leaves. Two plants, which died at an early stage, were completely white. In some of the striped plants only the bottom leaves of the three primary tillers were affected, the younger leaves being completely green. The majority, however, showed striping up the third or fourth leaves, but two plants up to the fifth leaf, although with a decreasing amount of white lines in the younger leaves. One plant, ex C. No. 108 (Victor), was found only shortly before heading. Both its tillers had distinct yellowish stripes on all their leaves*. In all plants the amount of striping varied considerably in the various tillers of the same plant.

The affected lines included forms of the Spelta and Emmer Series (see table), both including varieties of varied origin. Since all variants were found by chance during field observation and cultivation, not in the course of a systematic search, it is more than likely that the actual number of variants present was a multiple of those identified. It is remarkable that not one variant was found in any of the older New Zealand varieties, although large plots of these were searched for the occurrence of defective plants.

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* In a violent storm shortly before harvest both ears were broken off the straws, having been tied to a stick. Ears in the vicinity of the plant were collected from the ground, but no chlorophyll defects appeared in the progeny.

Cons. No., 1930.	Coll. No.	Name and Origin.	Number of Variegated Plants.	Progeny Raised.
Triticum vulgare.				
—	S 1237	Marquis 10B (Canada)	1	V 1
108	279	Victor (England)	1	—
1412	4 and 5	Serajevo 2 (Jugoslavia)	1	—
1543	267	Svalof's Riddar (Sweden)	1	V 12
1622	1282	Szekacs 17 (Hungary)	1	V 10
1534	287	Marster's New White Ideal (England)	1	V 13
1627	1287	Mindszenti 403 (Hungary)	2	V 11
1709	89	Belgrade 1 (Jugoslavia)	1	—
2086	622	Portugal 22	1	—
2572	1173	Duri (Australia)	1	—
3626	1358	Feldsberger Grannen Weizen (Czechoslov.)	1	—
—	1271	Kanred × Marquis (U.S.A.)	1	V 2
—	184	Dioseg No. 2 (Czechoslov.)	1	V 3
3289	1485	Persia 86	1	V 9
Triticum turgidum.				
2738	E 56	Greece 24	1 (white)	—
2979	351	Egypt 18	1	V 4
3037	406	Egypt 69	2	—
3199	601	Iraq 19	1	—
3167	553	Cyprus 12	1	V 8
Triticum durum.				
2801	E 129	Valencia 3 (Spain)	1	V 5
2817	146	Portugal 1	1	V 6
2818	147	Portugal 1	1	V 7
2838	169	Portugal 29	1 (white)	—

Total: 25, in 23 lines.

All seeds from 13 variants, including all the more pronounced cases of striping, were sown in 1931, and a systematic search for defective plants was conducted also in the Collection, consisting of over 2000 lines. However, no chlorophyll defects were found in the variant-progenies, nor in the Collection.

The exceptionally hard winter of 1930 can hardly be adduced for causing these somatic variations, since the following winter, in the course of which no defects arose, was even harder. It is equally unlikely that the high temperatures probably encountered by the seed in the course of the transport to New Zealand may have caused these variations—in analogy to the heat-induced, apparently non-inheritable chlorophyll defects in maize (Hull and Grossman, 1932)—since the defects occurred in the second progeny from imported seed, and none had been found in the first generation.

It seems more than likely that a plasmatic disturbance in the early embryonic stages caused the defects described. There appears to be a similarity to the heat-induced chlorophyll defects in maize (Hull and Grossman, 1932). However, no explanation can be offered as to the factor causing the defects in the former case.

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STADLER, L. J., 1930. Some Genetic Effects of X-Rays in Plants. *Jour. Her.* 21: 3-19.

The High-Tidal Mollusca of Rangitoto Island, Auckland; with Descriptions of a New Genus and Two New Species.

By A. W. B. Powell, Conchologist, Auckland Museum.

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The writer is a member of an Auckland committee that in 1925 received a New Zealand Institute Research Grant for the purpose of making an ecological survey of the Waitemata Harbour. The present paper is based upon a few observations made and some specimens collected in the course of this investigation. Of special interest is the discovery of a new genus of the *Ellobiidae,* described in this paper, which, so far as is known, is restricted to the shores of Rangitoto Island.

A full report on the animal communities of the harbour is in preparation, and will be published at a later date.

The thanks of the writer are due to Miss L. M. Cranwell for the identifications of the seaweeds and maritime plants mentioned herein.

The foreshore along the southern coast of Rangitoto Island is formed of extensive lava-flows, many of which are broken up into loose blocks, and these are strewn upon a substratum of stiff mud with occasional patches of *Zostera* and small areas of comminuted shell.

The typical inter-tidal plant cover on this southern coast ranges from a low-tidal *Carpophyllum* brown-algal community, through a mid-tidal community of *Corallina-Hormosira* (which thins out above amongst a zone of rock-oysters, *Ostrea glomerata*), to a moderately broad high-tidal zone, which is dominated by the glass-wort, *Salicornia australis* Soland. Together with the *Salicornia* two other maritime plants are moderately common. They are *Suadia maritima* Dum. and *Samolus repens* Pers. It is the fauna of this *Salicornia* zone which extends from about high-water neap to a little above high-water spring tide levels, that is made the subject of this paper.

In the uppermost part of the high-tidal zone the *Salicornia* thins out, and is replaced by scattered clumps of tussock, *Stipa teretifolia* Stued.

This marks the extreme landward limit of marine mollusca at this locality, one species only, the common periwinkle, *Melarhaphe oliveri,* being known to occur. Of all the high-tidal molluscs this periwinkle has the greatest vertical range, being found throughout the *Salicornia* belt and for a little distance both above and below it.

Although the glass-wort does not directly support the animals associated with it, cover is provided for a small inconspicuous dark green alga, *Rhizoclonium hookeri* Keietz, which grows upon the shaded mud surface, and is eaten in a living state by two species of mollusca, the ever-present pulmonate, *Ophicardelus costellaris,* and a minute taenioglossid, *Assiminea vulgaris.* Associated with these molluscs are a few amphipods, isopods, and the crabs *Hemigrapsus sexdentatus* (M. Ed.) and *Heterozius rotundifrons* (M. Ed.).

In depressions among the rocks, masses of decaying wrack accumulate, made up for the most part of remnants of low-tidal brown algae *Carpophyllum maschalocarpum* (Turn.) Grev. and *C. plumosum* (A. Rich.) J. Ag., with intermingled *Zostera nana.*

This accumulation of decaying vegetative matter supports large numbers of half to full-grown individuals of the pulmonate mollusc *Marinula filholi,* while the decaying *Zostera* in particular is favoured by numerous *Assiminea vulgaris.*

Beneath the decaying algae are loose stones which rest upon or are partly imbedded in mud, and upon these occur large numbers of the young of *Marinula filholi,* together with *Assiminea vulgaris* and a second taenioglossid, *Suterilla neozelanica,* while underneath in contact with the mud a further three species are to be found. Two of these (one a new genus of the pulmonates) are organic-mud feeders which receive their sustenance by retrieving from the mud minute particles of decaying algae and animal detritus. The third species, a new *Kellia,* occurs in vast numbers, but the two pulmonates are by no means common.

At Rangitoto the food of *Melarhaphe* consists for the most part of an obscure dark greenish, almost black lichen, which is rendered quite inconspicuous owing to the dark-coloured lava upon which it grows.

In other areas *Melarhaphe* is often found in numbers feeding upon the sea-lettuce, *Ulva,* and also upon *Enteromorpha,* a small alga which forms a pale green coating upon high-tidal rocks wherever fresh-water seepage occurs. Of all the high-tidal molluscs only one, *Melarhaphe,* is able to withstand long periods of desiccation, and on sunny days the stones upon which it occurs often become quite hot.

Contact with the sea at the high-tidal levels is very brief, so the remaining seven species owe their existence primarily to the moisture retained in the mud shaded by the *Salicornia* and to the dampness caused by the more or less permanent accumulation of decaying wrack, which is retained owing to the roughness of the rocks. Very little of the debris that once touches the shore at Rangitoto is ever washed away again by succeeding tides, so the conditions are rendered more or less permanent.

This stability of the high-tidal conditions, which means an ever-present abundance of food, can be taken as the main reason why the Rangitoto high-tidal fauna is so much richer than that of any other high-tidal area so far studied in New Zealand.

The *Salicornia* zone at Hobson Bay, Auckland Harbour, in sharp contrast to that of Rangitoto Island, has only two species of mollusca, *Ophicardelus costellaris* and *Melarhaphe oliveri,* the species *Marinula filholi, Suterilla neozelanica, Assiminea vulgaris, Kellia maoria,* and *Rangitotoa insularis* all being absent. However, this paucity of species may be due to some extent to the fact that the salinity of the waters of Hobson Bay is known to be slightly lower than at Rangitoto.

Summary of the Feeding Habits of the High-tidal Mollusca.

1. *Ophicardelus costellaris* feeds almost exclusively upon the living *Rhizoclonium hookeri* which grows on the mud under the shelter of *Salicornia australis*, but it has been observed also to eat decaying *Hormosira*.
2. *Melarhaphe oliveri* prefers the open, and will endure much desiccation by exposure to strong sunlight. At Rangitoto it feeds upon a small dark-greenish lichen, but it is also known to eat *Ulva* and *Enteromorpha*.
3. *Assiminea vulgaris* thrives equally well upon either living *Rhizoclonium* or upon decaying algae, especially *Zostera*.
4. *Marinula filholi* and
5. *Suterilla neozelanica* seem to live exclusively upon decaying algae, and at Rangitoto are found on and under stones beneath masses of decaying wrack.
6. *Kellia maoria* occurs on the under sides of stones, and no doubt obtains its staple food from the organic-mud in which the stones are immersed.
7. *Rangitotoa insularis* and
8. *Leuconopsis obsoleta* are organic-mud feeders which occur sporadically on the under sides of stones that are in contact with mud.

In brackish situations *Potamopyrgus antipodum* is often found living upon the mud in association with mangroves. *Caecum digitulum*, abundant elsewhere, has not yet been observed at Rangitoto; it seems to require smooth, soft rock, of which there is none at this locality.

ASSIMINEIDAE.

Subfamily *Assimineinae*.

Genus *Assiminea* (Leach) Fleming 1828.

(= *Syncera* Gray 1821, Med. Repos., p. 239. A nomen nudum, according to Thiele, 1927, p. 114.)

Type: (by subsequent designation, Gray 1847; for *Assiminea*). *A. grayiana* Leach = *Nerita Syncera hepatica* Gray 1821 (fide Gray 1857, p. 23 in Turton's British Shells).

Assiminea vulgaris (Webster).

1905. *Rissoia vulgaris* Webster. *Trans. N.Z. Inst.*, vol. 37, p. 277.
1913. *Rissoa (Setia) vulgaris* (Webster). Suter, *Man. N.Z. Moll.*, p. 216.
1913. *Barleeia chrysomela* Melv. and Stand. Iredale, *Pro. Mal. Soc.*, vol. 10, p. 370.
1915. *Notosetia vulgaris* (Webster). Iredale, *Trans. N.Z. Inst.*, vol. 47, p. 454.
1915. *Assiminea nitida* (not of Pease 1865). Oliver, *Trans. N.Z. Inst.*, vol. 47, p. 522.
1924. *Tatea hedleyi* Brookes. *Trans. N.Z. Inst.*, vol. 55, p. 153.
1926. *Assiminea nitida* (not of Pease 1865). Finlay, *Trans. N.Z. Inst.*, vol. 57, p. 379.

The first reference of the New Zealand shells to their correct family was in Finlay (1926, p. 379), where on Iredale's authority our species was referred to the widely distributed Polynesian *Assiminea nitida* (Pease). Finlay also mentioned that this species has been recorded from the Kermadecs by Oliver.

The species *nitida,* however, is not an *Assiminea,* as has been demonstrated by Thiele (1927, p. 128), for the dentition and open umbilicus show that it belongs to the genus *Paludinella.*

The writer has examined the dentition of Rangitoto specimens, which are topotypes of Brookes's *Tatea hedleyi,* and it is almost inseparable from that of *grayana,* the English genotype (as figured by Thiele l. c.), having the characteristic hinder denticles on the central tooth, and moreover the shell has the umbilicus closed, which is a characteristic feature of the genotype, but not of *nitida,* in which it is quite open. The open umbilicus in *nitida* was mentioned in Pease's original description, and this feature is clearly shown in specimens from Tonga in the Auckland Museum collection.

Furthermore, upon shell characters, Kermadec Island specimens are inseparable from New Zealand examples.

If Iredale's statement (l.c., 1913, p. 370) is correct, that the Loyalty Island *Barleeia chrysomela,* Melville and Standen (1896, *J. Conch.,* vol. 8, p. 309), is identical with the Kermadec Island shells, then it may be necessary later to change the specific name of the New Zealand shell once more. However, in the absence of Loyalty Island specimens, and taking into account both the poor condition of the holotype (as mentioned by Iredale, l.c., p. 370) and the fact that Iredale misidentified the Kermadec specimens as *nitida,* the wisest course meanwhile is to select an available New Zealand name for the New Zealand shell. This name comes from an unexpected source, as was revealed by a comparison between Webster's holotype of *Rissoia vulgaris* and topotypes of Brooke's *Tatea hedleyi,* which proved to be identical. It is possible that the combination *Assiminea vulgaris* has been used before, but I have not succeeded in tracing any such combination, so Webster's name may be employed for the New Zealand and Kermadec Island *Assiminea,* the type locality for which becomes Waipipi, Manukau Harbour.

Dentition (Fig. 7): The dental formula of *Assiminea vulgaris* is $1 + 1 + 1 + 1 + 1 + 1 + 1$. Central tooth with five cusps, and three denticles on each side, below. Inner lateral with six cusps and outer lateral with five. Marginal teeth with 15 pectinate cusps. The central tooth is a little broader, and the cusps more regular in size, otherwise the dentition of *vulgaris* is almost identical with that of the genotype.

Subfamily *Omphalotropidinae.*

Genus *Suterilla* Thiele 1927.

Type (original designation): *Cirsonella neozelanica* Murdoch.

Suterilla neozelanica (Murdoch).

1899. *Cirsonella? neozelanica* Murdoch. *Pro. Mal. Soc.,* vol. 3, pt. 6, p. 320.

1909. *Acmella neozelanica* (Murdoch). Thiele, *Arkiv. fur Naturgeschichte 75, Jahrg.*, vol. 1, pt. 3, pp. 387-390.
1913. *Cirsonella neozelanica* Murdoch. Suter, *Man. N.Z. Moll.*, p. 155.
1913. *Acmella neozelanica* (Murdoch). Suter, *Man. N.Z. Moll.* p. 1082.
1927. *Omphalotropis (Suterilla) neozelanica* (Murdoch). Thiele, *Zool. Jahrbucher*, vol. 53, pp. 124 and 127.

Thiele (1927, pp. 124 and 127), in proposing *Suterilla* as a new section of the genus *Omphalotropis*, remarked upon the similarity of its dentition to that of *Omphalotropis* rather than to that of *Acmella*, under which genus he had placed it formerly (Thiele 1909, pp. 387-390). Thiele now shows that on dental characters the genus *Acmella* belongs to the subfamily *Assimineinae*, whereas *Suterilla* is typical of the *Omphalotropidinae*.

However, unlike *Omphalotropis*, which is exclusively terrestrial, *Suterilla neozelanica* is as much a marine species as its associates *Marinula, Ophicardelus*, and *Kellia*, and, moreover, is so distinct from *Omphalotropis* on shell characters, being small and globular without an umbilical keel, that it may well be given full generic status.

ELLOBIIDAE.

Genus *Rangitotoa* n. gen.

Type: *Rangitotoa insularis* n. sp.

Odhner, in his systematic key of the Ellobiidae (1925, pp. 1-15), which is based largely upon dental characters, has divided the family into six subfamilies—the *Carychiinae, Melampodinae, Pedipedinae, Pythiinae, Cassidulinae*, and the *Ellobiinae*.

The first three of these form a major group, having the radula characterised by pectinate marginals with one or more ectocones, while the remaining three subfamilies are grouped together on the common character of blunt chisel-shaped marginals without ectocones.

The new genus *Rangitotoa*, here described, has a type of dentition characteristic of the first group of subfamilies, but the dentition is nevertheless distinctive, and not in accord with that of any genus belonging to the first group of Odhner's subfamilies.

The dentition suggests a position for these shells between the *Carychiinae* and the *Melampodinae*, nearer, no doubt, to the latter. The small dental formula, together with the obsolescent tricuspid nature of the central tooth, indicates a position not much in advance of the *Carychiinae*, and yet not as specialised as in the *Melampodinae*, in which all traces of the tricuspid central have vanished.

With regard to the laterals, the large mesocone* recalls the *Melampodinae*, but the presence of both a definite ectocone and an obsolescent entocone are features discordant for that subfamily.

The shell, however, is not unlike the West Indian *Tralia, (Melampodinae)*, but it lacks the characteristic thickened process within the outer lip, which is a feature of that genus.

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*The main or middle cusp of lateral and marginal teeth is termed the mesocone, while cusps situated on the inner side are known as entocones and those on the outside as ectocones.

Rangitotoa insularis n. sp. (Fig. 1).

Shell minute, semi-transparent, imperforate, thin, and colourless. Outline ovate-cylindrical, spire conical, less than half height of aperture. Whorls seven, slowly increasing at first, including a minute smooth protoconch of one flattened whorl. Aperture long and narrow. Outer lip thin and sharp, without a ridge or any processes within. Inner lip with three plaits, uppermost weak and not plainly visible from without, situated at a little above half the height of aperture. Central plait large and prominently projecting; lower plait less prominent, merging below into the thickened narrowly rounded basal lip. Surface smooth except for faint irregular axial growth lines.

Dentition (Figs. 5 and 6): Radula very minute, the detail of the teeth being difficult to see even with a sixteenth oil immersion objective. Dental formula small (12 — 16) + 1 + (16 — 12). Central tooth with one large cusp and an obsolete denticle on each side of it; laterals 16, each with a mesocone and an ectocone; marginals 12, each with an entocone, a mesocone, and from two to four ectocones.

Height, 3.7 mm.; diameter, 1.9 mm. (holotype)
„ 2.9 mm.; „ 1.4 mm. (average size specimen).

Holotype: In Auckland Museum (collected by A. W. B. P., March 12, 1930.

Habitat: Rangitoto Island; type from near the "Beacon." Found living only near high-water mark, on the under sides of stones which are partly in contact with mud. The writer has found this species to be distributed around the southern and western sides of Rangitoto Island, but so far has failed to discover it elsewhere.

Genus *Marinula* King 1831.

Type (by monotypy): *Marinula pepita* King.

Marinula filholi Hutton 1878.

This species shows considerable adaptability, and this accounts for its wide distribution around New Zealand shores. At Rangitoto *filholi* lives under stones and among decaying algae in muddy situations within the high-tidal zone, but it has been recorded by Oliver (1923, p. 499) from "between tide marks" at Island Bay, Cook Strait, and the writer has observed it on the open coast at Cape Foulwind, Manukau North Head, and Muriwai, living on cliff faces at above high-tide mark in situations where fresh-water seepage occurs.

Dentition: The dental formula (not previously recorded) is 121 + 1 + 121. The central tooth has one simple cusp, the laterals from two to three and the marginals from four to five cusps. The radula is very small, and the individual teeth are crowded and difficult to see.

It is also of interest to record that *Marinula striata* Odhner occurs abundantly at Mason's Bay, Stewart Island. Formerly this species was known only from the Auckland and Antipodes Islands. The Mason's Bay specimens were found alive and in numbers by Mrs R. H. Harrison, of Stewart Island.

Genus *Leuconopsis* Hutton 1884.

Type (original designation): *Leuconia obsoleta* Hutt.

Leuconopsis obsoleta (Hutton 1878).

This species is found in the sheltered harbour bays towards high-tide, usually in company with *Caecum digitulum* and *Onchidella patelloides*. It occurs sometimes on the open coast, and at Muriwai it is associated with *Marinula filholi*, and lives on cliffs just above high-tide mark, in situations where fresh-water seepage occurs.

Dentition (Figs. 3 and 4): Hutton, 1884, *Trans. N.Z. Inst.*, vol. 16, p. 213, gave the formula $\frac{55 + 1 + 55}{150}$ but he was unable to make out the form of the teeth. The radula is certainly very minute, the detail of the teeth being very difficult to see even with a sixteenth oil immersion objective. Dental formula small (16 + 39) + 1 + (39 + 16). Central tooth with one large elongated cusp, on each side of which is an obsolescent base of a former side cusp. The base of the central tooth is shaped like an inverted T. The laterals, which number 39, are each prominently bicuspid; both cusps, of which the mesocone is the larger, being long and slender and inclined outwards. Marginals 16, pectinate, each with an entocone, a mesocone, and an ectocone, all three of which are moderately long and of almost equal length.

Although the dental formula is smaller than is usual in the *Pedipedinae*, the character of both the teeth and the shell in *Leuconopsis* is most in accord with that subfamily.

ERYCINIDAE.

Genus *Kellia* Turton 1822.

Type (subsequent designation, Herrmannsen 1846): *Cardium rubrum* Mont.

Kellia, W. Turton. Conch. Insul. Brit., pp. 19, 56, 1822. Examples: *Kellia suborbicularis* (Montagu) and *K. rubra* (Montagu). *Kellia*, Turton, Herrmannsen, Indicis Gen. Malac., vol. 1, p. 568, 1846. "Typus: *Cardium rubrum* Mont." *Lasaea*, Leach in Brown, Ill. Conch. Gt. Brit. Ed. 1, Pl. 20, Figs. 17-18, 1827. Sole example, *L. rubra* (Montagu).

Grant and Gale (1931, p. 302) have shown that owing to Herrmannsen's type designation in 1847 of *Cardium rubrum* Montagu, the well-known genus *Lasaea* becomes a synonym of Kellia, and also that the genus *Chironia* Deshayes 1839 is available for the well-known species "*Kellia*" *suborbicularis.*

Kellia maoria n. sp. (Fig. 2).

Shell small, ovate, thin, moderately inflated. Colour creamy-buff without any other colouration. Interior of the same uniform colour. Beaks low and broadly rounded. Anterior end slightly longer than posterior end; both broadly rounded. Margins sharp and smooth. Hinge well developed, but not so heavy as in most species of the genus. Teeth typical, a minute cardinal and two pairs of laminae in the right valve; a cardinal and an anterior and a posterior lamina in the left valve. Resilium large, extending from the cardinal along the lower edge of hinge-plate. Surface of valves crowded with somewhat irregular microscopic concentric threads, but without wrinkles or punctures.

The species is characterised by its uniform buff colour without darker tinting, lack of wrinkles, and punctures, and its almost straight dorsal margin which does not descend under the umbo as in *australis* (Lamk.) and *rossiana vexata* (Finlay).

Length 2.40 mm., height 1.95 mm., thickness (two valves) 1.50 mm. (holotype). *Holotype* in Auckland Museum (collected by A. W. B. P., December 7, 1930.

Habitat: Rangitoto Island, Auckland. On under sides of stones in the high-tidal zone (type). Awanui Heads (W. La Roche, 1922); Lyall and Island Bays, Wellington (A. W. B. P.); Chatham Islands; and Paterson Inlet (A. Hamilton collection).

Wherever it occurs this species is usually found in great abundance. It lives on the under-sides of stones which are in contact with mud, but only between high-water neap and high-water spring tide levels.

The genus *Kellia* is now represented in New Zealand by the following four species:—*rossiana* (Finlay 1928), *rossiana vexata* (Finlay 1928), *hinemoa* (Finlay 1928), and *maoria*, Powell 1933. *Lasaea neozelanica* Suter must be removed from this association of species, as it proves to be a synonym of Webster's *Kellia bifurca,* for which Finlay (1926, p. 463) has provided the genus *Arthritica.* The main characteristic of *Arthritica* according to its author is the formation in adolescence of two internal thickened limy patches. The writer has examined the holotype and over 100 of Webster's paratypes of *bifurca,* and found that typical specimens were uncommon, the predominant form having the limy patches scarcely visible. Furthermore, the presence of limy patches was by no means restricted to the larger specimens. The type of *L. neozelanica* is a large thin-shelled specimen without the limy patches.

At first it seemed possible to recognise two varieties—one, the typical *bifurca,* having limy patches combined with a faintly trapezoidal outline, and the other, with undeveloped limy patches and a more regularly ovate outline. However, the type of *neozelanica* and a few others from North and South Island localities combine the *bifurca* outline with the absence of limy patches. It is inevitable that the two be merged, for there is also much variation in the strength of the hinge-plate, convexity, and external sculpture.

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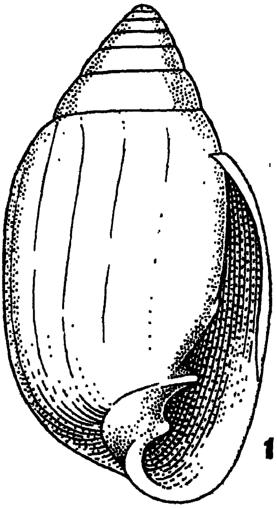

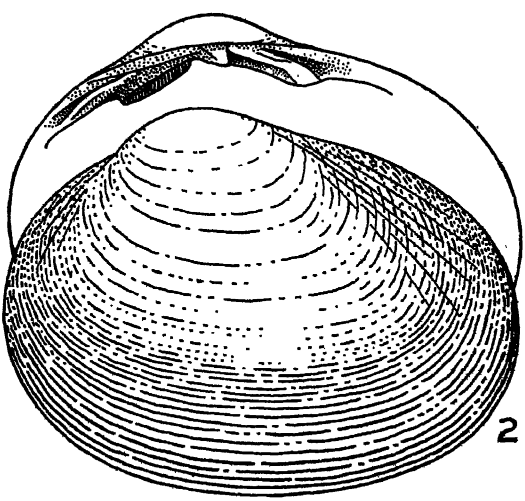

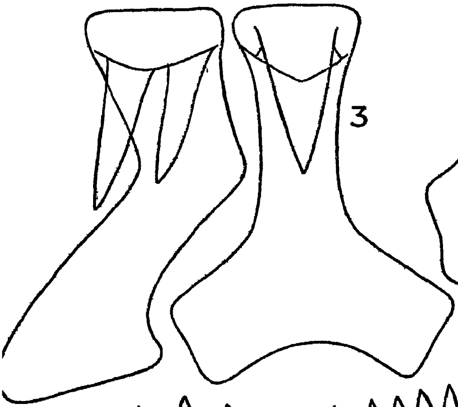

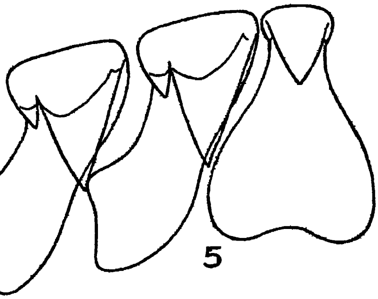

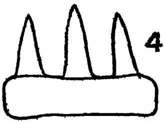

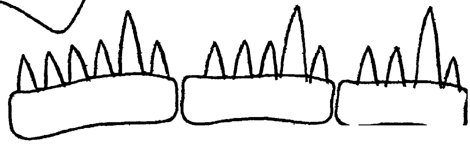

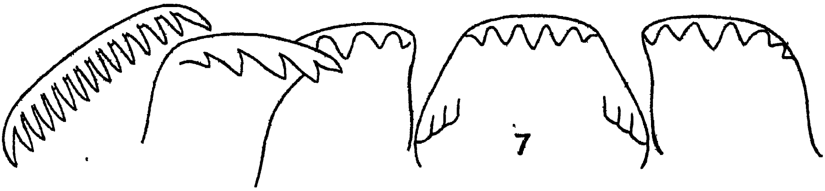

DESCRIPTION OF TEXT FIGURES.

FIG. 1.—*Rangitotoa insularis* n. gen. and sp. Holotype × 18.

FIG. 2.—*Kellia maoria* n. sp. Holotype × 27.

FIG. 3.—*Leuconopsis obsoleta* (Hutton). Central and innermost lateral tooth of radula.

FIG. 4.—*Leuconopsis obsoleta* (Hutton). Marginal tooth of radula.

FIG. 5.—*Rangitotoa insularis* n. gen. and sp. Central and two lateral teeth of radula.

FIG. 6.—*Rangitotoa insularis* n. gen. and sp. Marginal teeth of radula, from left, ninth, second, and first respectively.

FIG. 7.—*Assiminea vulgaris* (Webster). Radula.

Notes on the Taxonomy of the Recent Cymatiidæ and Naticidæ of New Zealand.

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An attempt is here made to determine the taxonomic relationship of a number of genera of the families *Cymatiidae* and *Naticidae*. This is based upon combinations of what is considered to be the main taxonomic characters.

The writer's thanks are due to Miss M. K. Mestayer for the radula of *Globisinum venustum,* and to Dr H. J. Finlay for the loan of types and other specimens, as well as for some opinions concerning the genus *Charonia.*

I.—The CYMATIIDAE.

Owing to their great diversity and the superficial similarity of many of their members, the triton genera of the families *Cymatiidae* and *Bursidae* have been always a source of worry to the systematist.

The characters that are here considered to combine taxonomic importance with simplicity in application are as follows:—Three unrelated external features are supplied by (a) the operculum—a secretion of the foot; (b) the protoconch—the embryonic phase of the species; and (c) the post-nuclear shell—a secretion of the mantle of the animal (post-larval to adult). A feature of internal secretion is furnished by (d) the radula. In the case of one genus the male genital organ furnished an important distinction where other characters were less divergent.

In the key given below the family *Cymatiidae* is divided into three subfamilies, each of which is characterised by a distinctive combination of dental and opercular characters.

With regard to the protoconch, there are only two types in the species dealt with—Finlay's " Apex A," which is described as " tall, narrowly conical, pointed, of about four whorls set slightly oblique to the axis of the shell, entirely coated with a persistent brown horny envelope . . ." and his " Apex B," which " is similarly polygyrate, but turbinate, with globose rapidly increasing whorls, usually wider than high, the tip minute and planorbid, set almost symmetrically on shell, polished, white and shining, with no trace of horny envelope " (see Finlay, 1931, p. 8).

However, as shown by the key, the protoconch in the tritons suggests grouping that is found to be at variance with results indicated by the sum of other taxonomic characters.

Recently, Finlay (1931, p. 9) has pointed out that while no two species that have different types of apices can be classed together in the same genus, it does not follow that all species having the same type of apex belong to one group unless the sum of taxonomic characters is in complete agreement.

KEY TO SOME OF THE MORE IMPORTANT TRITON GENERA.

CYMATIIDAE.

Shell with posterior notch at most.

- Lateral teeth plain.
  - Central tooth broad and low, with almost straight basal margin.
    - Operculum with apical nucleus.
      - Subfamily *Ranelliinae.*
        - Apex (?) *Ranella* Lamk., 1816. Gt. *gigantea* Lamk.
        - Apex (B) *Mayena* Iredale, 1917. Gt. *australasia* Perry.
- Lateral teeth denticulate.
  - Central tooth broad and low, extremities upcurved, no basal plate.
    - Operculum with subapical nucleus.
      - Subfamily *Charoniinae.*
        - Apex (B) *Charonia* Gistel, 1848.
  - Central tooth broad and high, with arcuate basal margin.
    - Operculum with apical nucleus.
      - Subfamily *Cymatiinae.*
        - Apex (?) *Cymatium* Bolten, 1798. Gt. *femorale* Linn.
        - Apex (B) *Cabestana* Bolten, 1798. Gt. *cutaceus* Linn.
        - Apex (B) *Austrosassia* Finlay, 1931. Gt. *parkinsonianum* Perry.
        - Apex (B) *Argobuccinum* (K) Herm., 1846. Gt. *argus* Linn.
        - Apex (A) *Monoplex* Perry, 1811. Gt. *parthenopeum* v. Salis.
        - Apex (A) *Lampusia* Schumacher, 1817. Gt. *pileare* Linn.

BURSIDAE.

Shell with well-developed posterior canal.

- Lateral teeth denticulate.
  - Central tooth with lateral prolongations of the base.
    - Operculum with lateral nucleus.
      - Apex (B) *Bursa* Bolten, 1798. Gt. *bufonius* Gmel.
      - Apex (?) *Gyrineum* Link, 1807. Gt. *spinosa* Lamk.

TYPES OF APEX.

Apex (A): "Tall, narrowly conical, pointed, of about four whorls, set slightly oblique to the axis of the shell, entirely coated with a persistent brown horny envelope . . ."

Apex (B): "Similarly polygyrate, but turbinate, with globose rapidly increasing whorls, usually wider than high, the tip minute and planorbid; set almost symmetrically on shell, polished, white, and shining, with no trace of horny envelope."

(Finlay, 1931, p. 8).

With regard to genera occurring in New Zealand, the status of *Fusitriton* has yet to be determined as the dental characteristics of that genus are unknown to the writer. It is probable, however, that the relationship will prove to be with the *Ranelliinae.*

All tritons evidently pass through a very efficient free-swimming larval stage which is characterised by an apical shell allied to the type known as *Sinusigera.* A very young shell of *parthenopeum* from Tom Bowling Bay has an apex of the *Sinusigera* shape, except that it lacks the characteristic claw. The *Sinusigera* apex is always associated with species of wide distribution, and Iredale (1911) has noted its presence in species of the families *Mitridae, Buccinidae, Nassariidae, Thaisidae, Pyrenidae, Coralliophilidae, Turridae,* and *Terebridae.*

Of the 13 species of tritons found in New Zealand seas only five have developed into recognisable regional species or subspecies, the remaining eight being considered to be identical with species known to be widely distributed in Australasian waters and elsewhere.

Two more species of the widely distributed type are herein recorded as new to New Zealand waters, and a third New Zealand species, previously recorded as identical with a South-western Australian species, is now described as a distinct regional subspecies.

Genus CABESTANA Bolten, 1798.

Type (subsequent designation, Dall, 1904), *Murex cutaceus* Linn.

Cabestana waterhousei segregata n. subsp. (Pl. 23, Fig. 3).

1927. *Cymatium waterhousei* (Adams & Angas) Powell. *Trans. N.Z. Inst.*, vol. 57, p. 560.

Waterhousei sensu lato occurs Recent in South Australia, Tasmania, the Kermadecs, New South Wales, and New Zealand, and a closely related fossil species is known from the upper Pliocene of New Zealand. The first specimen found in New Zealand waters was recorded by the writer in 1927; it came from Parengarenga Harbour in the far north. Recently, however, the writer found two living specimens among a quantity of *spengleri* which were taken on low-tidal rocks near Cornwallis, Manukau Harbour.

Although Australasian specimens are all referrable to *waterhousei* in a broad sense, the collection of series has shown that there are well-marked regional and bathymetric forms. Iredale (1929, p. 177) has described the New South Wales deep-water form as *C. waterhousei frigidulum,* and Finlay has named a New Zealand Castlecliffian fossil *C. debilior.*

The writer finds that recent specimens from New Zealand, the Kermadecs, and Tasmania represent one type, which is separable from South Australian littoral topotypes, the New South Wales deep-water form, and also the New Zealand Pliocene fossil. The New South Wales *frigidulum* and the New Zealand Pliocene *debilior* are both deep-water forms which have considerably taller spires than littoral shells.

The new subspecies *segregata* differs from South Australian typical *waterhousei* (Pl. 23, Fig. 1) in having a more capacious body-whorl and narrower and sharper varices. Furthermore, the primary spiral ridges are more prominently raised, and there are two instead of three keels showing on the spire whorls.

Height 60 mm.; diameter 33.5 mm. (holotype).
„ 52 mm.; „ 30 mm. (Parengarenga specimen).
„ 67 mm.; „ 38 mm. (Tasmanian specimen).

Holotype in writer's collection.

Habitat.—Near Cornwallis, Manukau Harbour (A. W. B. P., 6/11/1927) (type) and Parengarenga Harbour, New Zealand (W. La Roche); Sunday Island, Kermadecs (R. S. Bell); Frederick Henry Bay, Tasmania (W. H. Webster collection).

Dentition (Text Fig. 4).—The central tooth is very different in outline from that of either *spengleri* or *bolteniamum.* However, as it has a median shallow sinus of the front margin it stands nearer to the former species. The whole tooth, however, is much broader than that of *spengleri,* and the basal margin is a simple concave arc without a convex central projection. The central tooth has seven or eight denticles on each side of the central cusp, and the laterals mostly six denticles. In *spengleri* there are eight small denticles on each side of the central cusp, and from five to seven on the laterals.

Cabestana bolteniana (A. Adams). (Pl. 23, Figs. 5-8.)

1854. *Triton boltenianus* A. Adams. *P.Z.S.*, p. 311, *Hab. Australia (Mus. Cuming).*
1881. *Triton boltenianus* A. Adams. *Tryon, Man. of Conch.*, vol. 3, p. 17.
1929. *Cymatium bolteniamum* (A. Adams). Iredale, *Rec. Aust. Mus.*, vol. 17, no. 4, p. 173 (Pl. 41, Fig. 7).

For many years Australian writers have relegated this name to the synonymy of *C. spengleri.* However, Iredale has recently reinstated the species in the New South Wales faunal list, recording that it is quite distinct from the young of *spengleri,* and that it apparently never grows larger than the example figured (Pl. 41, Fig. 7), which is about 40 mm. in height.

The writer has recently found *bolteniana* in New Zealand waters. The first example obtained was a small living specimen from Mount Maunganui, Bay of Plenty, but later 50 well-preserved shells were gathered from an accumulation of sand and shells on a rocky beach at Kapo Wairua, at the extreme eastern end of Spirits Bay, North Auckland.

The finding of series covering intermediate growth stages clearly demonstrates the distinctive characters of the two species. Young *spengleri* of the size of adult *bolteniana* have much taller spires, are more angular, less thickened, and not so inflated. Furthermore, *bolteniana* grows a labial varix only in the adult shell, whereas *spengleri* leaves a varix at each growth stage.

The finding of this shell in numbers on a New Zealand beach shows that the species is now an established member of our fauna.

DESCRIPTION OF NEW ZEALAND SPECIMENS.

The original Latin description is a short one, unaccompanied by a figure or even dimensions. Iredale (1929, l.c.) supplied a figure of a New South Wales specimen which he had matched with the type, but gave no description, so the following notes on the New Zealand material will not be out of place.

Shell thick and ponderous, but rather small, usually about 30 to 40 mm. in height, although occasional specimens attain a size up to 55 and 60 mm. Unlike *spengleri,* which has several irregularly disposed varices, *bolteniana* forms a labial varix only in the adult stage.

Sculpture consisting of flat-topped, strongly raised, spiral carinae, those near the periphery being rendered nodulous by the presence of broadly rounded axial folds, which number 10 to 12 on the body-whorl. On the body and penultimate whorls the spiral carinae each become bisected by a median thread-like groove, and each of the intercarinal spaces is occupied by a secondary spiral. The whole of the post-nuclear whorls are crossed by closely packed flattened axial riblets, which have linear interspaces and their outer edges sharp, often delicately lamellate, for the attachment of the epidermis This epidermis is thin, with a delicate narrow frill along each of the axial riblets, the whole being crossed by regular spiral threads which are crowded with short bristles. The primary spiral carinae number six on the early spire whorls and 10 on the body-whorl. Spire blunt and low, very little more than half the height of the aperture. Outer lip much thickened, externally by a heavy varix and internally by a denticulated callus. Post-nuclear whorls four, protoconch missing in all specimens examined. Inner lip with a strong tubercle above, bordering posterior canal and numerous weak spiral plications, which extend down the whole length of the parietal callus.

Height	38 mm.;	diameter	25 mm.	Spirits Bay, New Zealand (Figs. 6-8).
„	36 mm.;	„	23 mm.	
„	36 mm.;	„	24 mm.	
„	37 mm.;	„	24.5 mm.	Ballina, New South Wales (Fig. 5).

Habitat.—Kapo Wairua, Spirits Bay, North Auckland (A. W. B. P., Feb., 1932); Mount Maunganui, Bay of Plenty (A. W. B. P., 1922); Taurikura Bay, Whangarei Heads (Miss A. M. Gillman). Also found in Tasmania and New South Wales.

Dentition.—Mount Maunganui specimen (Text Fig. 5).

The central tooth in this species has an outline quite distinct from that of either of the two related species, *spengleri* or *waterhousei.* The most marked difference is in the front margin of the tooth, which is a simple arc without a median sinus. There are six moderately strong denticles on the laterals in *bolteniana.* The marginals in all three species are very similar to one another.

Kapo Wairua specimens in Auckland Museum collection, Mount Maunganui specimen in writer's collection.

Cabestana labiosa (Wood)*. (Pl. 23, Fig. 9.)

1828. *Murex labiosus* Wood. *Index. Test Supp.*, p. 15 (Pl. 5, Fig. 18).

1881. *Triton labiosum* (Wood). Tryon, *Man. of Conch.*, vol. 3, p. 17 (Pl. 9, Figs. 64 and 65).

1910. *Cymatium labiosum* (Wood). Iredale, *Proc. Mal. Soc.*, vol. 9, p. 73.

1915. *Cymatium labiosum* (Wood). Oliver, *Trans. N.Z. Inst.*, vol. 47, p. 528.

1929. *Cymatium labiosum* (Wood). Iredale, *Mem. Queensland Mus.*, vol. 9, pt. 3. p. 280.

This adds another new record to the New Zealand fauna. A single well-preserved specimen, not long dead, was picked up by the writer on the beach at Takapaukura, Tom Bowling Bay, northernmost New Zealand, on the 16th February, 1932.

Some confusion has been caused regarding the identity and distribution of this species, owing to the fact that Tryon (1881), followed by Iredale (1910), considered the Australian *strangei* to be a synonym of *labiosa.* Later, however, Iredale (1929) admitted that *strangei* was distinct from *labiosa.* The most obvious difference between the two species is in the form of the canal, that of *strangei* being almost straight, while that of *labiosa* is conspicuously twisted.

Oliver (1915) recorded the dead shells of *labiosa* as frequent on the beaches of Sunday Island, Kermadec Group. All the Sunday Island specimens that the writer has seen are identical with the New Zealand shell.

The main characters of the species are the sharply raised sculpture and twisted and recurved canal. The whole surface of the shell is crowded with sharply raised spiral ridges, all of which are delicately beaded, due to close and regular transverse axial grooving. There are four massive keels on the body-whorl, the uppermost being widest and strongest. Each of the lower keels is surmounted by three closely spaced spiral ridges, but the peripheral spiral is a double one bearing six ridges. Apart from the axial grooving there are distant, strong, fold-like axials which become prominently nodulous at the periphery. Spire equal to height of aperture without canal. Colour pinkish-buff tinged with orange.

Height 25 mm.; diameter 16.5 mm. (Tom Bowling Bay specimen).
„ 24 mm.; „ 15 mm. (Sunday Island specimen).

Tom Bowling Bay specimen in Auckland Museum collection.

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* This species is referred to *Cabestana* with some hesitation, as both dental and opercular characters are unknown to the writer. Although the shell of *labiosa* somewhat resembles that of *exarata*, the latter species belongs to *Monoplex*, which is characterised by a very different type of apex. The apex in *labiosa* is type "B" in shape, and differs from that of *Cabestana* only in the presence of a brown horny envelope. However, this envelope peels off readily, and is not a persistent feature, as in type "A" apices.

Genus Monoplex Perry, 1811.

Type (fide Iredale, 1915), *Monoplex australasiae* Perry = *M. costata* Born = *Cymatium parthenopeum* (Von Salis).

Monoplex parthenopeum (Von Salis).

After comparing a series of New Zealand littoral and dredged specimens with a few from New South Wales, the writer was unable satisfactorily to apply Finlay's (1926, p. 398) statement that "New Zealand specimens have a longer canal, a different outer lip, and a considerably smaller aperture than Australian shells," and in consequence the use of Hutton's name *Triton acclivis* for the New Zealand shells is not considered necessary. In fact, among the specimens examined those with the longest canal and the smallest aperture respectively were from the New South Wales littoral.

Dentition (Text Fig. 7).—The central tooth is broader and lower than in *Cymatium, Cabestana,* or *Austrosassia,* and the laterals are quite distinctive in outline and in the erect position of the main cusp.

Monoplex is here separated generically from *Cabestana,* as the protoconchs differ radically, that of *parthenopeum* being type "A," polygyrate, with persistent horny envelope, while that of *cutacea,* the genotype of *Cabestana,* is type "B," polygyrate turbinate, without a horny envelope.

The dentition of *exaratum* is not known to the writer, but it is assumed to be of the *Monoplex type,* as both *parthenopeum* and *exaratum* have identical protoconchs, and their shells are not dissimilar.

Genus Charonia Gistel, 1848.

The classification of the Australasian species of *Charonia* presents many difficulties, some of which cannot be satisfactorily settled until a wider range of material is assembled for study. However, the few notes contained in this paper, while not adequate for a comprehensive review of the Australasian species, may prove useful to some future monographer equipped with more extensive material.

At one period Iredale (1915, p. 459) considered that Australian, Kermadec, New Zealand, and Mediterranean specimens were all one species, and recommended that they should bear the name *lampas* Linn. Later, in Finlay (1926, p. 397), Iredale reconsidered his previous decision and admitted that there was geographic localisation.

The first obviously necessary separation is that of the Mediterranean *lampas* from the New Zealand species. This is evident from the dentition, although no shells have been compared. Troschel (see Tryon, 1881; Pl. 2, Fig. 5), whose figures of molluscan dentition were always faithfully drawn, has shown that the lateral teeth of *lampas* have four denticles, and the central, six denticles on each side of the central cusp, whereas the writer has found that North Island specimens ascribed to *capax euclioides* have only three denticles on the laterals, and the central tooth has only five denticles on each side of the central cusp.

Another species that has been rightly separated from *lampas* is the Australian littoral *rubicunda.* This shell is characterised by spirally striate early whorls without nodules. Dr. Finlay has called the writer's attention to an Australian Tertiary species (*Charonia* n. sp. from "Abattoirs Bore," Adelaide, South Australia, older Pliocene) that has similarly sculptured early whorls, showing that the *rubicunda* type of shell has long been established in Australian waters. There are two types of *Charonia* in Australia, the littoral *rubicunda,* which is a broad obtuse-spired shell and a deeper-water more slender type, *euclia,* which differs from *rubicunda* in having nodulous early whorls. Apparently the two are not directly related, for in Western Australia the littoral *rubicunda* does not occur, although *euclia* is found in the deeper waters of that area.

Likewise in New Zealand, two types of *Charonia* are distinguishable, one broad and obtuse-spired, shaped like the New South Wales *rubicunda,* and the other slender and similar to the Western Australian *euclia.* Both, however, have nodulous keels on the early whorls, so are evidently not directly derived from *rubicunda.* The identification of shells from Northern New Zealand is difficult, owing to the fact that the types of Finlay's species, *capax* and *capax euclioides,* were both from moderately deep water off Otago Heads, and that apart from the holotypes no further specimens from South Island localities have been collected.

The common benthal form of *Charonia* in the North Island waters is very similar to the Otago Heads *capax euclioides,* and is here tentatively regarded as being conspecific. Certainly northern shells are not quite so slender, nor have they so many keels exposed on the later spire whorls. However, this discrepancy is explained by the fact that the holotype of *euclioides* is an abnormally coiled specimen, which exposes more of the keels than would obtain in a normal specimen. Although the writer has classed all the slender northern shells as *euclioides,* later it may be necessary to separate subspecifically the northern littoral shell, a form characterised by bright colouring, and found at the Kermadec Islands as well as in Northern New Zealand. However, the status of several exotic species needs to be investigated before the identity of this form can be settled.

With regard to *capax,* there are northern shells of similar proportions to the holotype, but they present differences in sculpture and in colouration, and here again, in the event of a series of southern shells becoming available, the northern shells may prove to be distinct.

Variation in this genus is so great, however, that for the present all the New Zealand *Charonias* are best referred to either *capax* or *capax euclioides.* The main characteristic of *capax,* apart from its broad shell and squat spire, is the persistence of the spiral cords, which are not interrupted by the nodulous keels. In *capax euclioides* the shell is more slender, and the spiral cords become obsolete on the nodulous keels.

A good figure of the northern "*capax*" appeared in Bucknill's "Sea Shells of New Zealand," 1924 (Pl. 4, Fig. 3). This is one of a series of six specimens collected by Dr. Bucknill from under rocky ledges and around boulders near the "Stone Wharf," Pilot Bay, Tauranga Harbour. Eggs were observed on the side of a large boulder on July 27, 1922, and were described by Dr. Bucknill as pink, translucent, elongated, and clubbed at the free extremity. They were closely spaced and in a single layer.

The following measurements may be helpful in separating the two New Zealand forms:—

Height	165 mm.;	diameter	90 mm.;	spire	angle	55	*capax* (holotype, Otago Heads, 20 f.).
„	141 mm.;	„	86 mm.;	„	„	54	*capax* (Tauranga Harbour, littoral).
„	165 mm.;	„	116 mm.;	„	„	54	*capax* (Tauranga Harbour, littoral).
„	227 mm.;	„	138 mm.;	„	„	58	*capax* (Whangape, littoral).
„	210 mm.;	„	100 mm.; (estimated)	„	„	43	*capax eucliodes* (holotype, 20 f.).
„	193 mm.;	„	115 mm.;	„	„	46	*capax eucliodes* (Cape Colville, 25 f.).
„	170 mm.;	„	85 mm.;	„	„	44	*capax eucliodes* (Cape Colville, 25 f.).
„	150 mm.;	„	77 mm.;	„	„	44	*capax eucliodes* (Manukau Heads, littoral).
„	133 mm.;	„	69 mm.;	„	„	43	*capax eucliodes* (Great Barrier, littoral).
„	130 mm.;	„	68 mm.;	„	„	43	*capax eucliodes* (Kermadec Islands, littoral).
„	123 mm.;	„	74 mm.;	„	„	56	*rubicunda* (New South Wales, littoral).

Genus RANELLA Lamarck, 1816.

Type (subsequent designation, Children, 1823), *Ranella gigantea* Lamk. (see Grant and Gale, 1931, p. 734).

Ranella multinodosa (Bucknill).

1927. *Mayena multinodosa* Bucknill. *Trans. N.Z. Inst.*, vol. 58, p. 312 (Pl. 35, Fig. 2).

1930. *Fusitriton multinodosa* (Bucknill) Finlay. *Trans. N.Z. Inst.*, vol. 61, p. 249.

Bucknill's *multinodosa* is not a *Mayena*, nor does it belong to *Fusitriton*, to which genus it has been referred by Finlay. Both shell and dental characters show that its nearest relative is the genotype of *Ranella*, a species which is found in the Mediterranean, the south coast of Ireland, and along the Atlantic coast of Europe to the south of the English Channel.

Compared with the northern species, *multinodosa* has a more widely expanded body-whorl, and the spiral rows of tubercles are less regular. These vary in their relative strengths, the middle one being strongest and the two uppermost weakest; otherwise there is practically nothing to separate southern from northern shells.

The type of *multinodosa* is a dead shell which was inhabited by a hermit-crab, and came from the Cavalli Islands, near Whangaroa, in 25 fathoms. Recently the writer secured a live specimen and examined four others, all of which were trawled in 50 fathoms off Maunganui Bluff, West Coast.

Dentition (Text Fig. 1).—The central tooth is broad and rectangular, having a massive central cusp and four smaller cusps on each side of it. The central tooth in *Mayena australasia* is very similar, except that the side cusps are fewer and stronger. The radula of both *Ranella* and *Mayena* differs from that of all other tritons so far examined in the form of the laterals, which are entirely without denticles.

Genitalia.—The penis in *Ranella multinodosa* is broad and roughly rhomboidal in shape, quite unlike that of *Mayena,* which is long and leaf-like as in other species of the *Cymatiidae.* The most distinctive feature about the penis of *multinodosa, however,* is in the course of the seminal-furrow which first runs towards the outer edge, bends back at a sharp angle, runs back diagonally to the inner edge, and then continues along the inner margin right to the extremity (see Text Figs. 11, 12, and 13).

The long canal and curious male genital organ of *multinodosa* demonstrate the impracticability of merging *Mayena* with *Ranella* (= *Eugyrina*) as Hedley has done (1918, p. 66).

MAYENA Iredale, 1917.

Type (original designation), *Biplex australasia* Perry.

Mayena australasia (Perry).

1811. *Biplex australasia* Perry. "*Conchology*" (Pl. 4, Figs. 2 and 4).
1926. *Mayena zelandica* Finlay. *Trans. N.Z. Inst.*, vol. 57, p. 400 (Pl. 20, Fig. 66).

The writer hesitates to use the name provided by Finlay for the New Zealand shell, as no constant points of difference between New Zealand and Australian specimens are apparent when large series are examined.

Finlay (l.c.) stated that the New Zealand shell has "a subobsolete lower keel and many nodules on the peripheral keel (about nine between varices in specimen figured)." However, only a few of the New Zealand shells have as many as nine nodules between the varices, the average number for eight New Zealand specimens being 6.875, and for the same number of New South Wales specimens 6.625; the difference is negligible. Further, the majority of the New South Wales specimens examined also have the subobsolete lower keel, and in two instances this is more strongly developed than in any of the New Zealand examples.

Dentition (Text Figs. 2 and 3).—The radula of *Mayena australasia* differs from that of *Ranella multinodosa* only in the side denticles of the central, which are fewer and stronger, and in the shape of the laterals. The side denticles are so variable in shape, size, and number even in one radula that it is impossible to discriminate between New Zealand and New South Wales specimens.

It is probable that *Fusitriton* and *Priene* are related to *Ranella and Mayena,* but the writer has seen neither radulae nor opercula from the first mentioned genera.

NEW ZEALAND RECENT CYMATIIDAE.

Family *Cymatiidae.*

Subfamily *Cymatiinae.*

Cabestana spengleri (Perry, 1811).
Cabestana bolteniana (A. Adams, 1854).
Cabestana waterhousei segregata Powell, 1932.
Cabestana labiosa (Wood, 1828).
Austrosassia parkinsoniana (Perry, 1811).
Monoplex parthenopeum (Von Salis, 1790).
Monoplex exaratum (Reeve, 1844).
*Argobuccinum** *tumidum* (Dunker, 1862).

Subfamily *Charoniinae*†.

Charonia capax Finlay, 1926.
Charonia capax euclioides Finlay, 1926.

Subfamily *Ranelliinae.*

Ranella multinodosa (Bucknill, 1927).
Mayena australasia (Perry, 1811).
Fusitriton laudandum Finlay, 1926.

* Grant and Gale, 1931, p. 734, stated that "*Argobuccinum* should not be used as of Morch, 1852, but of Klein in Hermannsen, 1846, with the type *Murex argus* Linnaeus by original designation." Acting upon the assumption that *Argobuccinum* in Hermannsen, 1846, is not valid, Finlay (1926, p. 399) proposed *Gondwanula,* with *Ranella tumida* as type. The dentition of *tumida* (Text Fig. 8) is very similar to that of the South African *argus.* An interesting point is that the denticulate laterals and form of the central tooth indicate close relationship with the *Cymatiinae,* but nothing in common with *Mayena australasia* of the *Ranelliinae,* with which *tumidum* was formerly classified.

† *Charonia tritonis* (Linn.) is omitted from the New Zealand list, as the writer has not seen a single authentic New Zealand specimen, all of the Ahipara shells seen being extra large *capax.* Smith (1915, *Brit. Antarct. Exped., Moll.,* pt. 1, p. 84) has recorded a *Charonia species* from off the North Cape in 11-20 fathoms, but this is a juvenile only 11.5 mm. in length, and no doubt it is the young of *capax.* Evidently Smith compared the North Cape apex with that of the Australian *rubicunda,* a species which does not occur in New Zealand, and this would account for his statement that the protoconch in *rubicunda* is purplish, and the following normal whorls are finely spirally striated and without rows of pustules.

II.—THE NATICIDAE.

The facts here brought together by an investigation of the New Zealand Recent Naticoids prove so discordant with the accepted grouping, which is based primarily upon opercular characters, that obviously a drastic revision of the whole family is desirable. It would be inopportune, however, for the writer to attempt this at present, as there is neither sufficient material nor literature available for the purpose in New Zealand.

The classification of the New Zealand species, given below, is based upon what is considered to be the four main taxonomic characters of the family. They are the radula, the operculum, the protoconch, and the funicle. It was found that in some cases the operculum was very similar in species that differed radically in respect to the three other taxonomic characters; therefore the use of the operculum alone in the correllation of species cannot be regarded as a guarantee of genetic affinity. How else can we account for simple or bifid laterals, unicuspid or tricuspid central teeth, and three distinct types of apex* being present in one or another of the series *zelandica, australis, and migratoria?*

Application of the rule that no two species are closely allied unless all four of the above-mentioned taxonomic characters are identical would go a long way towards unravelling the phylogeny of a family that is hopelessly conservative in its superficial characters. It would mean the employment of a greater number of genera, but eventually a more natural classification would result.

It was soon realised that species with horny opercula are not so widely sundered from those with calcareous opercula as we have been accustomed to believe. For instance, the radula of the Eastern American *Polinices (Neverita) duplicata* Say has all the essential characters of that of the *marochiensis* series and the New Zealand *australis,* yet both of the latter have calcareous opercula.

The relationship of the horny operculate genera to the calcareous operculate series remains to be determined. No doubt many of those of the calcareous type have been derived, independently, at different times, from those of the horny type, and very probably the reverse also has taken place.

Cossmann (1919, p. 385) cited the case of *Natica dillwynni* Payr., which is stated to have an operculum partly horny and partly calcareous. Also, just as in the calcareous operculate genera, there are species of the horny operculate type with radulae having either simple or bifid inner marginals combined with a tricuspid central tooth, and at least two types of protoconch.

The evidence furnished by the facts of geographic distribution is also significant. Quoy and Gaimard's *zelandica,* for which Marwick (1931, p. 98) has proposed the generic name *Tanea,* is restricted to

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* The protoconch in *zelandica* is of three smooth flattened helicoid whorls, with a small tip, and a deeply impressed suture; that of *australis* is paucispiral of one and a-half whorls, the tip of which is a flattened blob; and that of *migratoria* is dome-shaped of three and a-half whorls, with a tiny planorbid tip.

New Zealand, and has an ancestry extending back to *Oligocene* times. The writer's *migratoria,* however, is found both in Northern New Zealand and New South Wales*, and is very closely allied to two other species of wide range, the tropical Pacific *gualteriana* and the North African *marochiensis.* Obviously this group has a more efficient pelagic larva than *Tanea,* and although the two are very much alike in shell and opercular characters, the diverse dental and apical features indicate that no close relationship exists.

No suitable generic name† for the *marochiensis* series appears to be available, so the new name *Notocochlis* is proposed, with *migratoria* Powell (1927, p. 560) as type. The genus is defined by the following combination of the four taxonomic characters. Protoconch dome-shaped, of three and a-half whorls, with a tiny planorbid tip + smooth calcareous operculum with a single marginal sulcus + well-developed funicle + radula with tricuspid central and bifid inner marginals.

The New Zealand *australis* represents another aberrant type. It is so like the horny operculate *vitrea* in shell features that when fossils minus opercula are considered their identity cannot always be definitely settled. Marwick (1924, p. 553) described his *denticulifera* as being related to *australis,* but also remarked that it may be related to *vitrea.*

A comparison between *australis* and *vitrea* shows that they both have a paucispiral apex, the tip of which is a somewhat immersed flattened blob, and also that the obsolete or nearly obsolete funicle is a feature of both species.

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* Finlay has wrongly rejected my claim that *migratoria* is found outside New Zealand waters, and has described the New South Wales shells as a new species, *Cochlis vafer* (1930, p. 232). Reconsideration of a series of specimens from both countries has strengthened the writer's original opinion that New Zealand and New South Wales specimens are identical, for the characters cited by Finlay as being peculiar to the New South Wales specimens are not always in evidence, and, further, are also present in some New Zealand topotypes.

† Woodring (1928, p. 379) has shown that owing to Iredale's designation of *Cochlis albula* (Bolten) as type of *Cochlis,* that genus becomes a synonym of *Natica* s. str. *Natica* s. str. is not available, as it has an operculum with two strong marginal ribs and denticles down the inner side, a different apex, and a radula probably with a unicuspid central and simple marginals as in *lineata,* a species which agrees with the genotype in all other respects (the radula of the actual genotype is unknown to the writer). *Naticarius* is also unsuitable, as it has a multispiral operculum, and the apparently congeneric Mediterranean *millepunctatus* Lamarck has a tricuspid central combined with simple marginals. *Tanea* also cannot be used, as it is one of the few naticoids with a unicuspid central, and in this respect it resembles *Natica* (s. str.) *lineata,* but the protoconch and details of the operculum are quite dissimilar in the two species.

As it has been shown that the same type of dentition is often found in naticoids quite irrespective of the horny or calcareous nature of their opercula, it is not unreasonable to postulate closer relationship between the *australis* and *vitrea* groups than has been recognised.

The reference of *australis* to any of the recognised calcareous operculate genera is not desirable, so it is accordingly separated as the type of another new genus, having probable relationship with the horny operculate *Uberella**. The characters of this new genus, which is named *Proxiuber,* are:—Protoconch paucispiral, the tip of which is a somewhat immersed flattened blob + smooth calcareous operculum with two linear marginal grooves + obsolete or nearly obsolete funicle + radula with tricuspid central and bifid inner marginals.

A radula of *Globisinum venustum* (Suter) (Text Fig. 19) was received from Miss M. K. Mestayer, of the Dominion Museum, Wellington, and this proves to have a very unusual central tooth that is quite unlike anything the writer has seen. However, as the genus can be traced back to the Cretaceous in New Zealand, and is now living nowhere else, it is not reasonable to expect very close similarity between the dental characters of *Globisinum* and those of other naticoids.

Marwick (1924, p. 574) has remarked on the resemblance of the shell of *Globisinum* to that of *Vanikoro* (i.e., *Merria*),but the dentition of *V. cancellatus* Lamk., a drawing of which was kindly made for the writer by Lieutenant-colonel A. J. Peile from a slide in the Gwatkin collection, makes it possible definitely to rule out any relationship with that genus and the family to which it belongs.

In *cancellatus* all the teeth, central, lateral, and marginals are profusely dentate, whereas in *Globisinum venustum* they are all smooth.

The shield-shaped base of the central tooth of *Globisinum,* with its two incipient hinder teeth or plates, is so peculiar that the writer has no hesitation in separating the genus under a distinct subfamily of the *Naticidae.*

Unfortunately, the operculum was shed prior to the specimen reaching the Dominion Museum.

A list of the New Zealand Recent Naticoids is given below.

With regard to the Tertiary species, the genus *Notocochlis* does not seem to occur, most of the calcareous operculate species being referrable to *Tanea,* except *denticulifera,* which probably belongs t *Proxiuber.*

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* The dentition of *Uberella* is not known.

Family *Naticidae.*

Subfamily *Naticiinae.*

Tanea zelandica (Quoy & Gaimard, 1832).
Notocochlis migratoria (Powell, 1927).
Proxiuber australis (Hutton, 1878).
Proxiuber denticulifera (Marwick, 1924).
Uberella vitrea (Hutton, 1873).
Uberella barrierensis (Marwick, 1924).
? *Uberella amphialis* (Watson, 1881).
Friginatica pisum Hedley, 1916.
? *Friginatica apora* (Watson, 1881).

Subfamily *Globisininae.*

Globisinum wollastoni Finlay, 1927.
Globisinum venustum (Suter, 1907).

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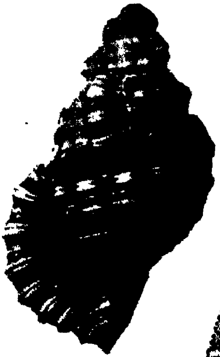
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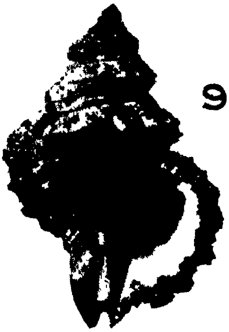
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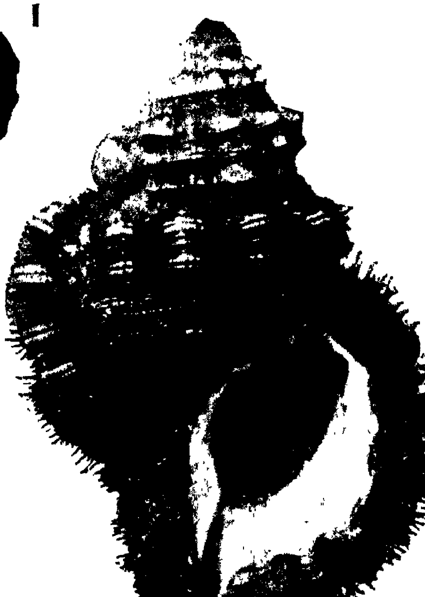
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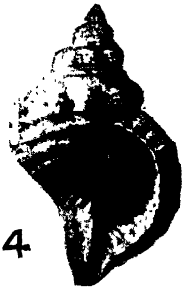
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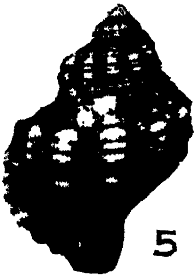
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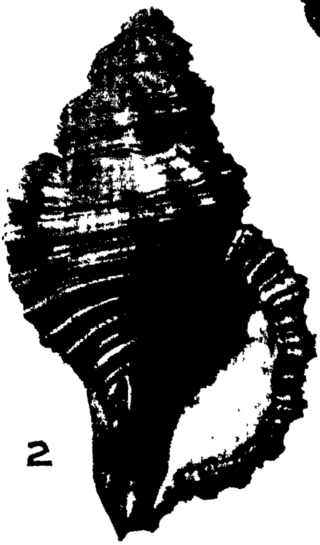
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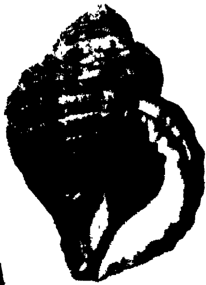
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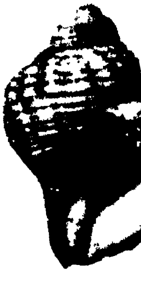
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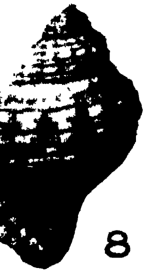
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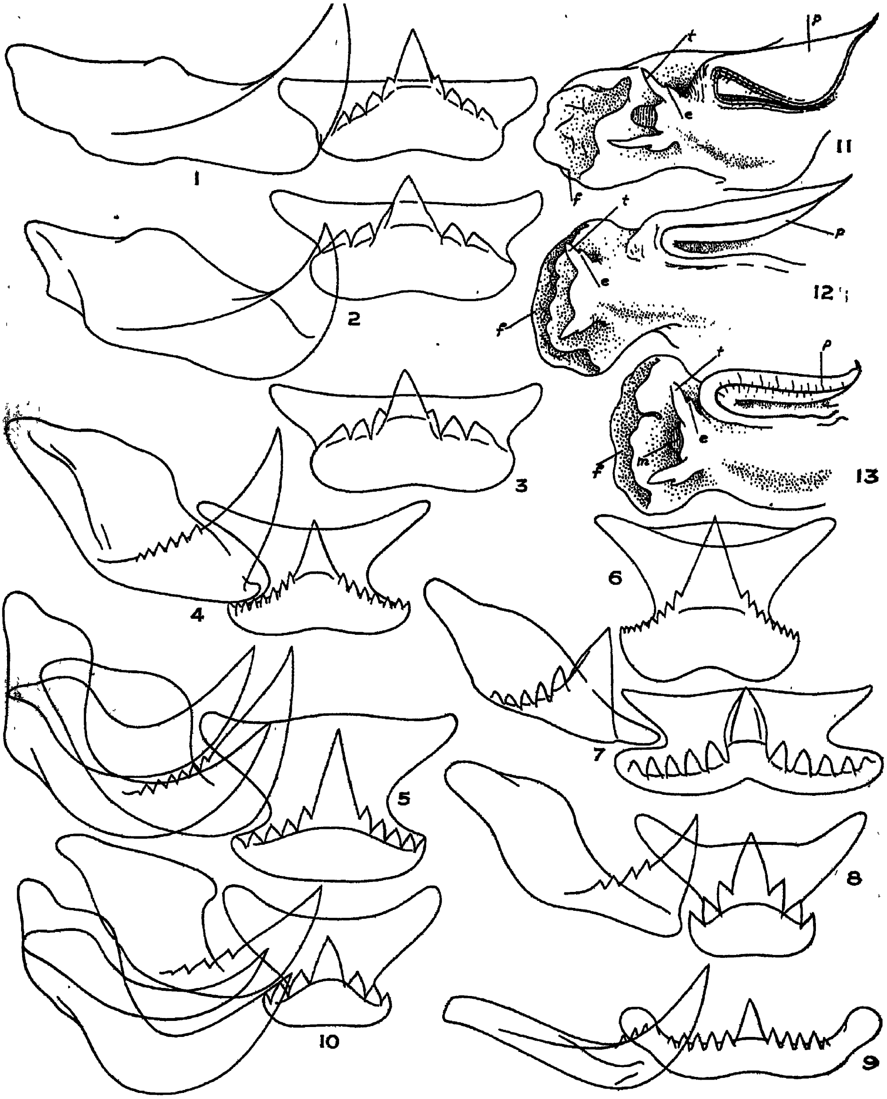
1.—*Cabestana waterhousei* (Adams & Angas). Hardwicke Bay, South Australia.

2.—*Cabestana waterhousei* (Adams & Angas). Western Australia.

3.—*Cabestana waterhousei segregata* Powell. (Holotype) N.Z.

4.—*Cabestana spengleri* (Perry). (Young specimen, Mount Maunganui, Bay of Plenty, N.Z.)

5.—*Cabestana bolteniana* (A. Adams). Ballina, New South Wales.



DENTITION OF THE CYMATIIDAE.

1.—*Ranella multinodosa* (Bucknill). Maunganui Bluff, in 50 fath., West Coast. Central and lateral.

2. and 3.—*Mayena australasia* (Perry). Shellharbour, New South Wales. Central and lateral.

4.—*Cabestana waterhousei segregata* Powell. Near Cornwallis, Manukau Harbour. Central and lateral.

5.—*Cabestana bolteniana* (A. Adams). Mount Maunganui, Bay of Plenty. Central, lateral, and marginals.

6.—*Cabestana spengleri* (Perry). Langholm, Manukau Harbour. Central.

7.—*Monoplex parthenopeum* (von Salis). Near Cornwallis, Manukau Harbour. Central and lateral.

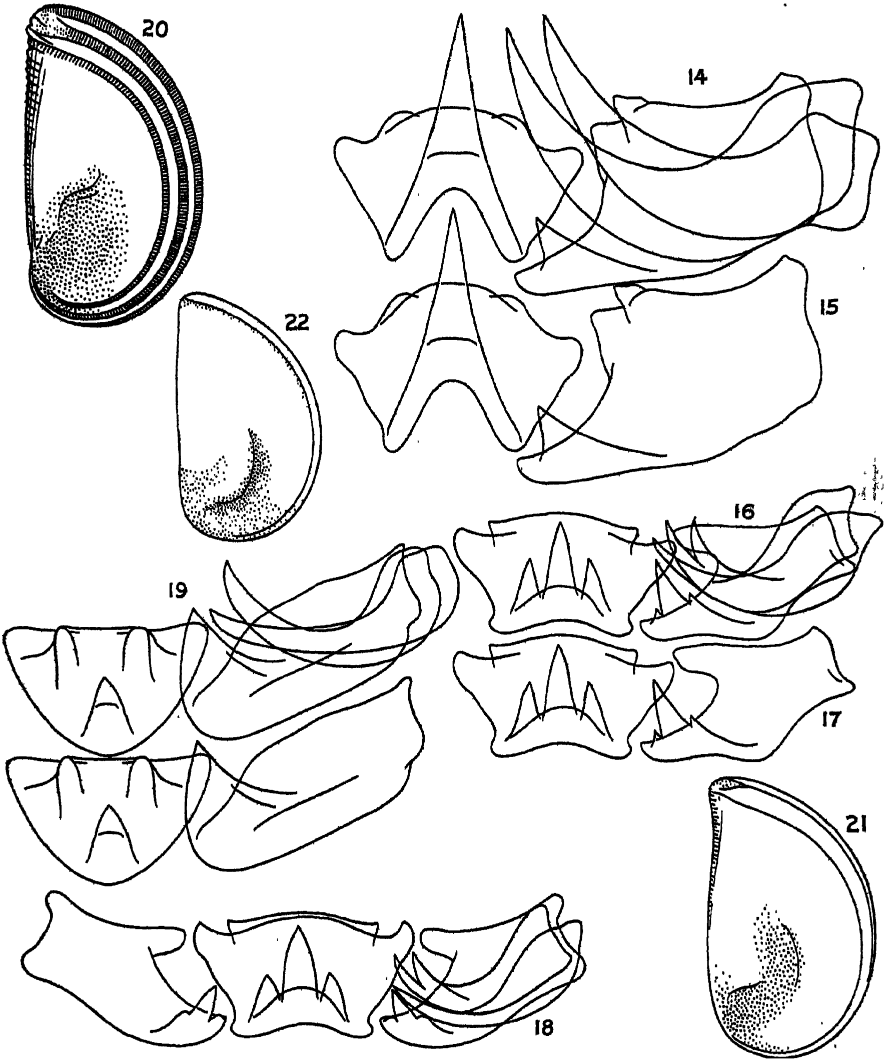
8. *Argobuccinum tumidum* Dunker. Castle Point, East Coast, Wellington. Central and lateral.

9.—*Charonia capax euclioides* Finlay. Off Mayor Island, in 25-30 fath., Bay of Plenty. Central and lateral.

10.—*Austrosassia parkinsoniana* (Perry). Taupo Bay, Whangaroa. Central, lateral, and marginals.

EXTERNAL FEATURES OF ANIMALS OF CYMATIIDAE.

11.—*Ranella multinodosa* (Bucknill). Maunganui Bluff, 50 fath.



DENTITION OF THE NATICIDAE.

14, 15.—*Tanea zelandica* (Q. & G.). Pohara Beach, Takaka. Central, lateral, and marginals.

16.—*Notocochlis migratoria* (Powell). Shellharbour, New South Wales. Central, lateral, and marginals.

17.—*Notocochlis migratoria* (Powell). Parengarenga Harbour, N.Z. (paratype). Central and lateral.

18.—*Proxiuber australis* (Hutton). Port Fitzroy, Great Barrier Island. Central, lateral, and marginals.

19.—*Globisinum venustum* (Suter). Cape Campbell, in 50 fath., Marlborough. Central, lateral, and marginals.

OPERCULA OF NATICIDAE.

atica vitellus Linn. (*rufa* Auct.) Samoa?

ea zelandica (Q. & G.). Mount Maunganui, Bay of Plenty.

chlis migratoria (Powell). Parengarenga Harbour (paratype).

Descriptions of New Zealand Fishes.

By L. T. GRIFFIN, F.Z.S., Assistant Director Auckland Museum.

[*Read before the Auckland Institute, 27th July, 1932; received by Editor, 5th September, 1932; issued separately, 28th February, 1933.*]

Family MURAENIDAE.

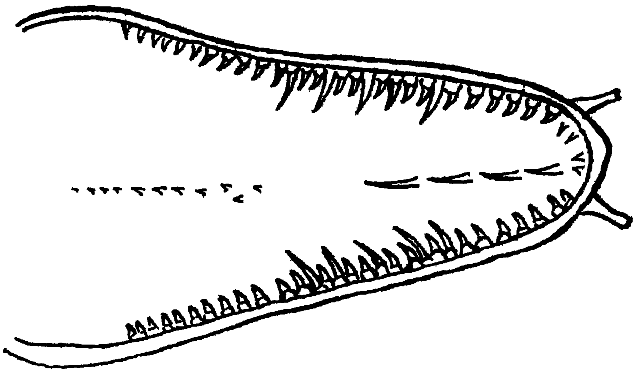
Genus MURAENA Linn.

Muraena tuhua n. sp. (Plate 24).

Head 8.98, height of body 12.44 in the total length. Eye three in snout or 16.36 in length of head, gape 2.47 in same. Gill-opening rather longer than diameter of eye. Anterior nasal tube little longer than .5 diameter of eye. Teeth in jaws 24 above, 21 below. Palatine teeth two, vomerine four.

Body moderately compressed, gradually becoming more so from about midway between vent and tip of tail. Occiput much elevated, firm, fleshy. Snout broadly convex, flattened on sides before the eye. Cleft of mouth extending almost the length of snout behind eye.

An outer series of fixed compressed, subtriangular, acute teeth in both jaws, with a few longer subulate depressable teeth forming an inner series. All the outer series have their bases well covered by grisly membrane. Vomerines subulate, the first fixed, those following depressable. The outer teeth at the apex in each jaw are very small, arranged in pairs. Palatine teeth subequal, small, acute. Tongue immovable.



Mureana tuhua. Upper jaw. Nat. size.

A series of four rather large open pores on the upper jaw, and five on the lower margin of the ramus. Anterior nasal tube short, much thickened at base, tips flattened. Posterior nostril in a low tube situated a short distance before the eye. Branchiostegal sac little developed, almost subequal with anterior part of body. Origin of dorsal fin only slightly in advance of gill-opening. It is low anteriorly, gradually becoming higher, reaching its highest point above the vent, thence continuing fairly straight to tip of tail which it surrounds. Anal fin very much lower. Both fins are thick and fleshy, showing no trace of rays.

Colour.—Body, uniform light chocolate profusely covered with pale cream spots of a great variety of sizes and forms, none of which is margined with a deeper colour. The spots are smaller and more crowded on the head, abdominal region, and tail, less so along the dorsal from the gill-opening to three-quarters the length of the fish. No fine lines or streaks are present on any part of the body, and the branchiostegal sac is also entirely free from any lines indicating the internal structure. Eye dull gold and blue-black.

Described and figured from a fine specimen which is 1617 mm. long from tip of snout to tail. Head 180 mm.; snout 37 mm.; mouth to angle 73 mm.; eye 11 mm.; tip of snout to middle of vent 767 mm.; middle of vent to tip of tail 850 mm.; greatest height of body 130 mm.

Affinities.—I cannot find any eel that fully agrees with this large and powerful specimen, the nearest to it being an equally large species named *Uropterygius obesus* figured in the *Rec. Austr. Mus.*, Vol. XVIII, Pl. XXXIX, Fig. 1, but a critical examination discloses important differences between the two.

In *M. tuhua* the much more advanced position of the dorsal and anal fins are particularly noticeable, and both completely surround the tail. There is also considerable difference in the arrangement of the teeth, while the posterior nostrils are short but well-defined tubes.

It is interesting to note that this is the first occasion a true *Muraena* has been recorded from New Zealand seas, *M. shirleyi*, also described in this paper, being the second member of the genus to turn up. The differences between the two are so obvious as to require no further remarks here.

Locality.—Caught on the hook in 80 fathoms of water 15 miles south-east of Mayor Island (Tuhua, after which I have specifically named this fish). Presented by Mr McLachlan, of Auckland, in August, 1928.

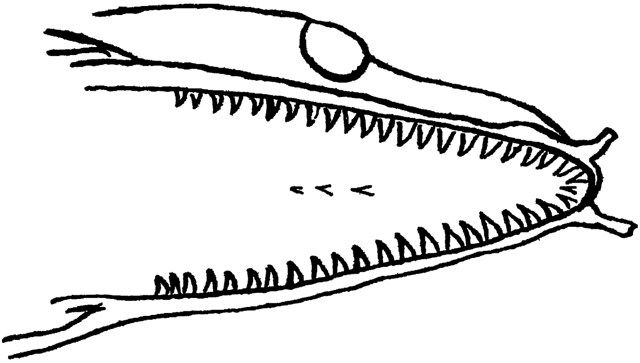
Holotype in the Auckland Museum.

Muraena shirleyi n. sp. (Plate 24).

Head 7.36, height of body 10.3 in total length. Eye 14, gape 2.15 in the head. Gill-opening equal to the diameter of the eye. Length of anterior nasal tube three-quarters diameter of the eye. Teeth in jaws 20 above, 24 below. Palatine teeth four. Vomerine two.

Body moderately compressed for three-fourths of length, thence becoming much more so to tip of tail. Occiput moderately elevated, fleshy. Snout broadly convex, somewhat flattened on sides. Cleft of mouth extends well behind eye, nearly equalling the length of snout.

Teeth in jaws uniserial, compressed, subtriangular, acute, directed slightly backwards, becoming smaller towards the angle. Vomerine teeth, subulate, depressable. Palatine teeth few in number, the anterior one largest, separated somewhat from the second. None of the teeth is serrated. Tongue immovable.



Muraena shirleyi. Upper jaw. Nat. size.

A series of three small pores on the ramus, with four on the margin of the upper jaw. Anterior nasal tube short and stout. The posterior nostril is a short tube situated almost above the anterior quarter of eye. Branchiostegal sac only moderately developed. Origin of dorsal fin nearly halfway between the gill-opening and eye. It is very thick and fleshy throughout its entire length, highest and thickest just before the vent. Anal very low and fleshy. Both fins surround the tail.

Colour.—Pale chocolate over all, slightly tinged with purple-brown on the ventral surface. Margin of dorsal and anal dark chocolate.

Body covered with a moderate number of opalescent bluish-white spots of irregular shapes and sizes, none of which are numerous. They are smaller on top of head, fewest in number on trunk, becoming more crowded and larger on the tail, where they are also brighter in colour. The dorsal portion of the fish has the greater number of spots, while the anal fin has six only very small rounded ones. All the spots are margined in dark chocolate brown. Numerous fine wavy lines of a darker colour than the general body colour are present, reaching from the dorsal to the ventral surface, while the folds of the gill membrane are very distinctly marked with several dark-brown zig-zag lines extending from the angle of the mouth to gill-opening. The latter is also splashed with dark brown and small streaks.

Angle of mouth similar to gill-opening. Top of snout and tips of nasal tubes dark brown. Eye, dark golden and blue-black.

Described and figured from an adult which is 1030 mm. long from tip of snout to tail. Head 140 mm.; snout 30 mm.; mouth 65 mm. to angle; eye 10 mm.; trunk 495 mm.; tail 535 mm.; greatest height of body 100 mm.

Affinities.—An extensive examination of the characters of a large number of marine eels fails to agree with those of the specimen here described. At first sight it might be taken for a pale variety of *G. prionodon,* but there are marked differences when closely examined. Apart from its very light colour and arrangement of the spots the teeth are greater in number, the origin of the dorsal fin is much in advance of that found in *G. prionodon,* while the eye is also much smaller, going as much as 13 in the head, and the posterior nostril formed as a low tube entirely disposes of its belonging to the genus *Gymnothorax.* I therefore feel safe in regarding this eel as a new species, and have named it after its captor, Mr J. S. Shirley, who has often enriched the Museum collections with new and interesting forms of our fish fauna.

Locality.—Mokohinau Islands, June, 1931.

Holotype in the Auckland Museum.

Family TRICHONOTIDAE.

Key to the genera of the Trichonotidae found in New Zealand:—

A. Origin of dorsal behind that of anal.
  (1) Eyes normal; interorbital of moderate width; no spine on end of maxillary.
  (2) Operculum and interoperculum scaleless, but with well-developed striae. Preoperculum denticulated. A flattened spine crossing the operculum.
  (3) Lateral line very low on body.
  (4) Whole of rays of dorsal and anal simple, articulated.

Tewara n. g.

B. Origin of dorsal in advance of the anal.
  (1) Eyes large; interorbital very narrow; a spine on end of maxillary.
  (2) Operculum and interoperculum covered with scales; preoperculum not denticulated; no spine crossing the operculum.
  (3) Lateral line in middle of the height of body.
  (4) Dorsal rays simple articulated, anal rays branched.

Hemerocoetes.

Tewara cranwelli n.g. et sp. (Plate 25). D. XXXV; A. XLII; P. XV; C. XIII $\frac{1}{1}$; V. i/V.

Depth 8.14, head 5.7 in the length to end of caudal peduncle. Eye 10 in head.

Head depressed anteriorly, broadest over operculum, covered ith moderate cycloid scales excepting the top of snout, operculum, interoperculum, the two latter bearing well-defined striae. n of preoperculum finely denticulated. Operculum with a flat- herent spine crossing its upper half. Eye moderate, high in head, cutting the profile. Interorbital space half diameter of eye, with a slight ridge mesially. Nostrils nearer tip of snout than eye, with a very low tube.

Mouth oblique, reaching backward beyond the posterior border of the eye, upper jaw slightly the longer, lower jaw extremely thin and weak.

Maxilla reaching somewhat beyond the posterior margin of eye, very thin and scaleless.

Minute, slightly hooked villiform teeth present in both jaws in a single series, and a small cluster still more minute on the vomer. Tongue free, elongate, pointed.

Gills four; gill-rakers nine approximately on lower half of the anterior limb.

Body sub-cylindrical, elongate, becoming compressed towards the caudal, the dorsal and ventral surfaces subequal, gradually tapering towards the peduncle, covered with small cycloid scales which extend forward to the interorbital. Lateral line, commencing at upper angle of operculum, descends abruptly behind the pectoral, and thence follows an almost straight course to end of peduncle; it is situated very low on the body, about quarter the distance from the anal base, well defined as a continuous series of small triangular spines directed forward.

Dorsal fin with its origin at the vertical from the third anal ray, composed entirely of simple articulated rays. Anal in every way similar to the dorsal, but the rays are somewhat shorter and greater in number. Caudal and pectoral similar in form to the dorsal and anal.

Colour.—Body pale golden brown, with a continuous series of dark brown blotches extending along top of back as far as end of peduncle. A smaller and more crowded series of blotches extends from top of operculum all along the middle line of body, and there are two conspicuous dark brown bands, narrowly joined in the centre, at the base of caudal.

The lateral line is slightly lighter than the body colour. Head with a dark mottled patch on the nape, and mottled brownish before the eyes and on snout. A blackish margin at the apex of both jaws. Operculum pale bluish and transparent. Eye mottled, the pupil blue-black. All fins immaculate.

Described and figured from a specimen which is 57 mm. long from tip of snout to end of caudal peduncle. Height of body 7 mm.; length of head 10 mm.

Since describing this specimen I have obtained another from Parengarenga, captured by the Museum collecting party while dredging at the entrance to Parengarenga Harbour on sandy bottom, February, 1932, and a third specimen was dredged about 1000 yards off Mount Maunganui, Ocean Beach, in the Bay of Plenty, from a clean, coarse, sandy bottom in March by Mr A. W. B. Powell. A critical examination of the three discloses no difference whatever, even the measurements are identical.

Localities.—Smugglers' Bay, Whangarei Heads, 2/11/31 (type), Parengarenga Harbour, North Auckland, February, 1932, and Mount Maunganui, Tauranga.

The type was brought to me by Miss Lucy Cranwell, after whom I have specifically named this fish. Holotype in the Auckland Museum.

Family GOBIDAE.

Genus CALLOGOBIUS Bleeker.

Callogobius atratus n. sp. (Plate 25). Br. 4; D. vi/I/X; A. i/X; P. XIII; V. 1/V; C. xvi/$\frac{6}{6}$

Depth before the ventrals 6.1 in the length to base of caudal rays, head 3.6 in the same. Eye 5 in head, subequal with the snout, and about 1½ in the interorbital space. Depth of caudal peduncle 2½ in the head, breadth of body before the pectorals 2¼ in the same.

Head depressed, much broader than deep, cheeks and opercles scaleless, having ridges of mucigerous papillae arranged as shown in the drawing accompanying this description. Eyes small, high in the head, slightly cutting the profile. Interorbital space flat, nostrils rather wide apart, tubular, the anterior with a tiny flap on the posterior margin.

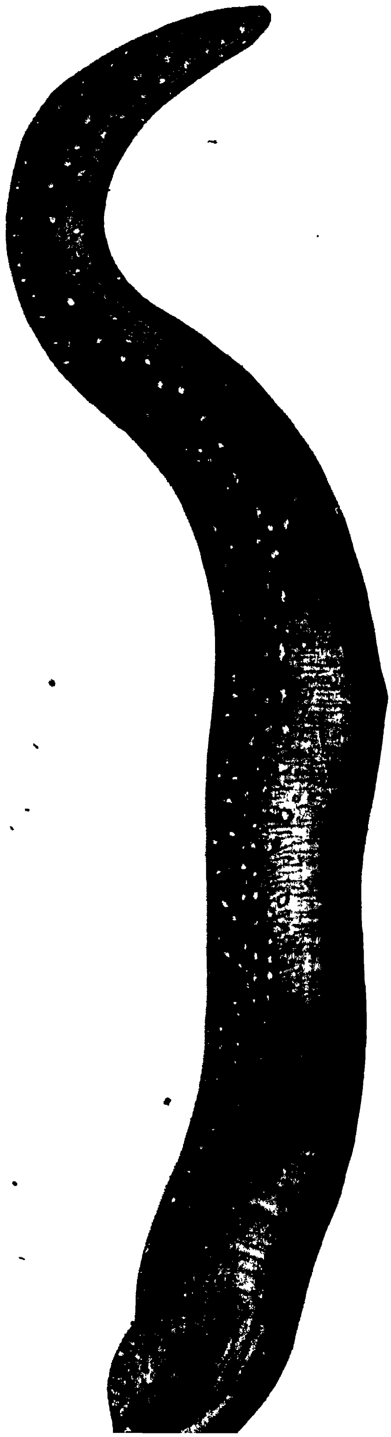
Snout somewhat elevated. Mouth oblique, the jaws equal when closed. Maxilla almost reaching the vertical of the orbital margin. A band of very fine villiform teeth in both jaws, the inner series being the longer, all directed backward. Tongue free, rounded anteriorly. Gill-opening lateral, not so broad as the separating isthmus. Shoulder girdle and base of pectoral quite smooth.

Body rounded anteriorly, gradually becoming compressed towards the caudal, where it is markedly so; it is covered with moderate cycloid scales adhering firmly to the skin. Scales completely cover the nape, and extend as far as the posterior margin of the maxillary. They are also present, but somewhat smaller on the breast and abdomen; those of the lateral line largest. Lateral line commencing at the shoulder-girdle quite straight throughout its entire length. Genital papilla prominent.

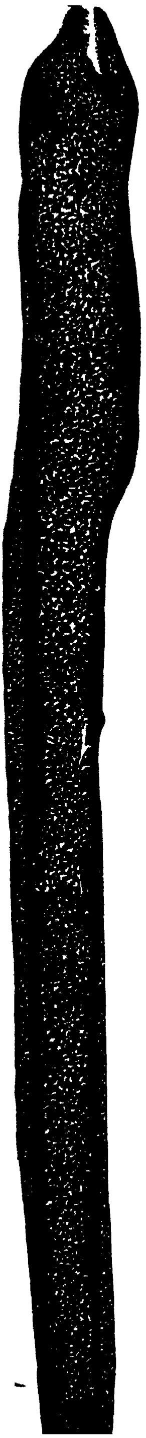
First dorsal fin originating above the anterior quarter of the pectoral, the rays being subequal in length.

Origin of second dorsal is the vertical from the third anal ray. It increases in length gradually backward, the fifth-seventh rays being longest, the last subequal with the first. Anal similar in form to the second dorsal, the rays are much longer, but its basal length is somewhat shorter than the former. Pectorals and caudal broadly rounded. Ventrals united at their base with a moderately broad membrane; they gradually increase in length to the fifth ray, which is longest.

Colour.—Uniform dull purple-brown below the lateral line, with lighter patches above, separated by darker lines. Cheeks and opercles with numerous very pale brown patches and mottling. Scales of

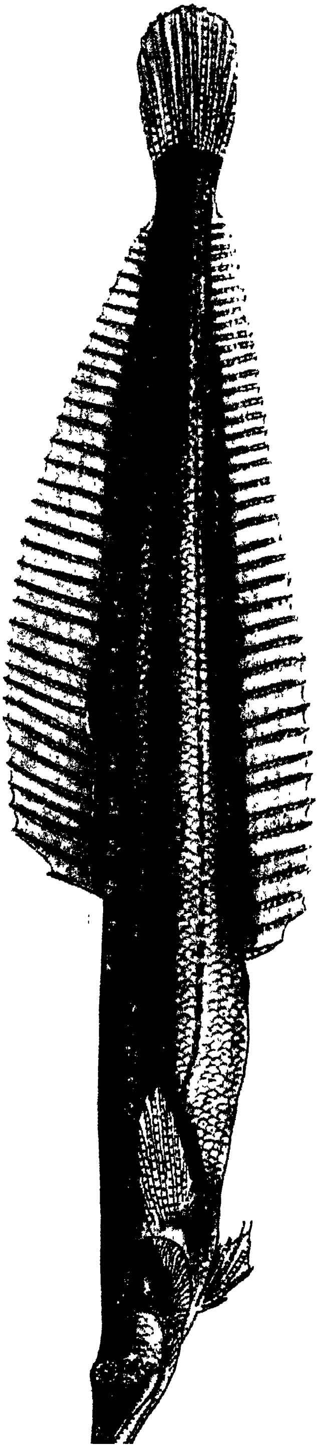


Muraena shirleyi n. sp

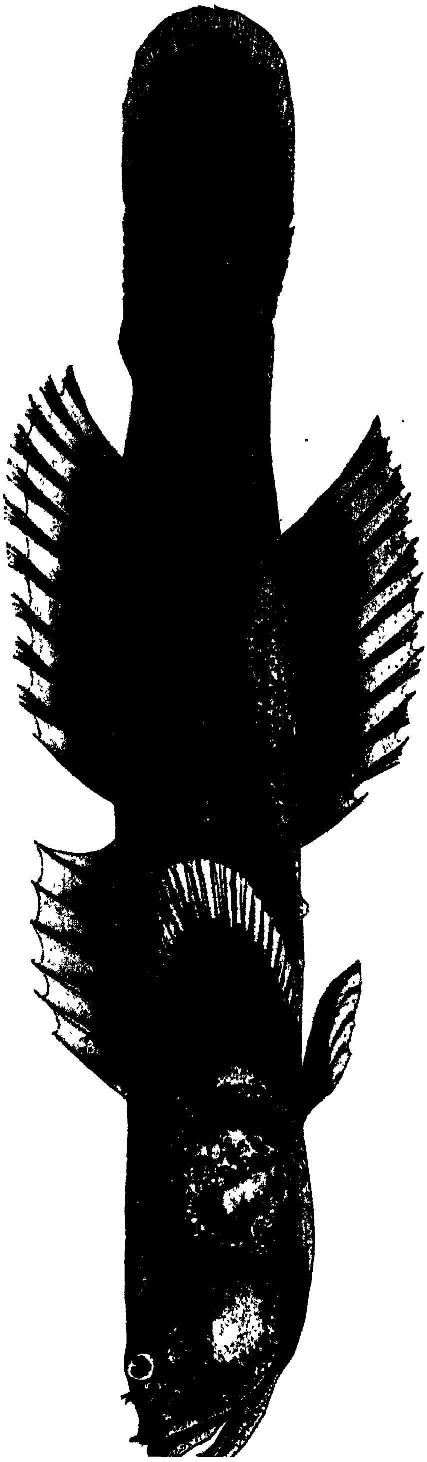


Muraena tuhua n. sp.

L. T. Griffin del



Tewara cranwelli. N. gen. et sp.



Callogobius atratus n. sp.

L. T. Griffin del.

lateral line with light brown margins. Vertical fins similar to the paler parts of the body, the tips darker. Caudal, pectorals, and ventrals with pale margins, dark brown from the base to more than half their length.

Described and figured from a specimen which is 55 mm. long, from tip of snout to base of caudal rays.

Variation.—Only four specimens of this fish have so far been obtained, and a careful comparison fails to show any variation whatever.

It is apparently a scarce species, as many hours of searching the locality from which these specimens came failed to produce more. It is also interesting to note that this is the first occasion the genus has been recognised from New Zealand. Several species of *Callogobius* are known from Australian seas, and Mr Gilbert P. Whitley, the zoologist to the Australian Museum, informs me that none is like the one here described. He points out that the Australian form *Callogobius hasseltii* differs in having larger scales, different disposition of papillae on head, and lighter colour. It also differs from *Metagobius sclateri,* which has the ventrals more separated, larger scales, and less elongate body, while from *Callogobius (Mucogobius) mucosus* it differs in having darker pectorals, and differently disposed ridges on the head.

Locality.—Four specimens from rock-pools, Cable Bay, Mangonui County, March, 1931.

Holotype and paratypes in the Auckland Museum.

The Metamorphic and Intrusive Rocks of Southern Westland.

By F. J. Turner, Otago University.

[*Read before the Otago Institute, 12th April, 1932; issued separately, 28th February, 1933.*]

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SCOPE OF WORK.

In a recent paper (Turner, 1930a) the writer gave a preliminary account of the metamorphic rocks and peridotites of the lower part of the Cascade Valley, South Westland, based upon observations carried out during January and February of 1929. The district was again visited early in 1930, with the object of investigating further the "Older Metamorphic Rocks" and ultrabasic intrusives of the Cascade Valley, and examining the metamorphic rocks of the region between the Haast and Cascade Valleys, where constant floods had rendered field work impossible during the 1929 expedition.

The present paper includes the results of this second visit, in so far as they apply to the metamorphic rocks, and the intrusive igneous rocks which frequently invade them. Observations were confined to the more accessible portions of this region, namely, the valleys of the Makarora and Haast Rivers, the coastal belt between the mouth of the Haast and the Arawata, and the Jackson, Matyr, and Cascade Valleys still further south.

The whole of this area is extremely rugged and mountainous, the peaks of the major chains ranging from 6000 feet to over 8500 feet in height, while the fast-flowing intervening rivers occupy deep and precipitous recently-glaciated valleys. The main rivers—the Haast, Okuru, Waiatoto, Arawata, and Cascade—rise among the permanent snowfields and glaciers of the Main Divide, and are liable to frequent summer floods as a result of torrential warm rains from the north-west. Except where isolated settlers have cleared the land in the vicinity of Okuru and the mouth of the Haast, dense forests cover the mountain sides to a height of a little over 4000 feet above sea-level, and effectively conceal the outcrops. On account of these natural difficulties and the inaccessibility of the area, detailed mapping was not attempted, and indeed would be possible in the future only if several months could be devoted to field work.

PREVIOUS WORK.

The literature referring to the geology of the Cascade Valley and the Jackson's Bay district has already been summarised (Turner, 1930a, p. 172).

In addition to this, a brief report on the metamorphic rocks north of the Haast River is given by Cox (1877a, pp. 72-74), while Haast himself (Haast, 1879, pp. 46-56) gave an interesting account of his early geological explorations in Southern Westland during 1862 and 1863, when he travelled from Lake Wanaka across the Haast Pass to the West Coast by way of the Haast Valley, returning later by the same route. In the same volume (pp. 249-265) a considerable space is devoted to the metamorphic rocks of Westland, which were divided by Haast into three groups: a lower series or Gneiss Granite Formation and two overlying series, the Westland and Waiho Formations respectively. Haast was unfamiliar with much of the country with which the present paper deals, and for this reason, and in the absence of descriptive petrography from his account, his work will not be considered further.

OUTLINE OF GEOLOGICAL HISTORY.

The basement rocks of Southern Westland are a series of hornfelses, gneisses, schists, phyllites, and slates which cover most of the area examined, and which are continuous with the Maniototo Schists of Central Otago on the east, and northwards with the schists of Westland, which extend throughout the full length of the province along the western flank of the Alps. On account of marked difference in metamorphic grade between the rocks respectively east and west of the peridotite belt, the metamorphic rocks of the Cascade Valley were originally tentatively divided (Turner, 1930a, p. 186) into a western or " Older Metamorphic Series," and an eastern series showing a lower metamorphic grade and correlated with the Maniototo Series of Central Otago. At the same time it was pointed out that the " Older Metamorphic Series " might later prove merely to be the more intensely metamorphosed equivalent of the Central Otago schists, a view which has since received strong support from evidence obtained further north in the Haast Valley. Stratigraphic subdivision of the metamorphic rocks is therefore considered no longer advisable, and the term " Older Metamorphic Series " has been dropped.

All the metamorphic rocks are now grouped in a single metamorphic series, which exhibits well the phenomena of progressive metamorphism on a regional scale. Subdivision based upon grade of metamorphism and chemical composition has been attempted. While most writers hold that the rocks of Westland were metamorphosed during the great orogeny of the Lower Cretaceous, the present writer believes that the date of metamorphism is much more ancient, and possibly even as remote as the Middle Palaeozoic.

Contemporaneously with the main metamorphism, deep-seated masses of granite now represented by pegmatites invaded the western portion of the area, where resultant hornfelsing is also much in evidence.

At a subsequent date the schists of the Cascade Valley were invaded by a great intrusion of peridotite, together with associated minor dyke-rocks, which is believed to have accompanied the folding movement of Lower Cretaceous times, and to be contemporaneous with the other ultrabasic intrusions of the South Island. All these rocks show signs of dynamic metamorphism resulting from shearing after intrusion, while the ancient metamorphic rocks of the Cascade and Jackson Valleys have suffered contemporaneous partial retrogressive metamorphism under epi-zone conditions.

Still later minor intrusives include diorite-pegmatites, and a group of tinguaites and camptonites which possibly belong to the Early Tertiary, and which have recently been described by the writer.*

Strongly folded Tertiary grits, sandstones, and limestones unconformably overlie the basement metamorphic and ingneous rocks, and are to-day represented by a small residual mass described by Cox (1877b) in the vicinity of the old Jackson's Bay settlement. Still more recent are the probably Late Pliocene conglomerates which underlie the Cascade Plateau, and outcrop along the northern wall of the lower Cascade Valley. The significance of these rocks has been discussed in a recent paper (Turner, 1930b, pp. 527-529).

In the latter publication the physiographic evolution of the southern half of the area now under consideration was dealt with, and need not now be recapitulated. It is sufficient to state that the whole area has been profoundly glaciated during Pleistocene times. Unconsolidated moraines belonging to this period are especially conspicuous on the surface of the Cascade Plateau, where they mantle the Pliocene conglomerates over an area of some 10 or 20 square miles.

Alluvium and river gravels form extensive infillings in many of the larger river valleys, while the shore-line from Jackson's Bay to beyond the Haast is flanked by a coastal belt, sometimes several miles in width, built up of Pleistocene and Recent alluvium and beach deposits.

The rocks of South Westland may be summed up in downward sequence as follows:—

(9.) Recent alluvium and beach deposits.
(8.) Pleistocene moraines and gravels.
(7.) Pliocene conglomerates of Cascade Plateau.
(6.) Mid-Tertiary marine sediments.
(5.) Tinguaites and Camptonites (? Early Tertiary).
(4.) Diorite-pegmatites.
(3.) Peridotites and associated minor intrusives (? Lower Cretaceous).
(2.) Granites and pegmatites (? Palaeozoic).
(1.) Metamorphic rocks (? Early Palaeozoic).

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* F. J. Turner, *Trans. N.Z. Inst.*, vol. 62, pp. 215-229 (1932).

PETROLOGY AND DISTRIBUTION OF THE METAMORPHIC ROCKS.

QUARTZO-FELDSPATHIC SCHISTS, GNEISSES, ETC.

In the majority of the metamorphic rocks of southern Westland quartz and feldspar in highly variable proportions are the dominant minerals, though either chlorite, muscovite, or biotite is always present as an additional essential constituent. These rocks are grouped by the writer as quartzo-feldspathic phyllites, schists, hornfelses, etc.

The rocks are further subdivided into nine distinct groups, each of which is characterised by a fairly constant mineral assemblage or texture, depending partly upon variation in chemical composition of the original rocks, but more especially upon the degree and type of metamorphism to which the rocks in question have been subjected. As would be expected, there is often a certain amount of gradation from one group to another, so that intermediate petrological types may be recognised in these instances.

(1.) *Slates and Phyllites:* True slates (Nos. 1289*, 1306) were found in one locality only, viz., in the vicinity of Haast Pass at the head of the Mule Valley, where they outcrop abundantly, striking approximately north and south, the dip being always nearly vertical.

They are fine-grained, silky grey rocks with a highly perfect slaty cleavage, which is crossed obliquely by closely spaced strain-slip planes. In section the average grain-size is seen to be about 0.01 mm., though individual grains may occasionally reach 0.1 mm. in diameter. The most important constituents are quartz, mica, epidote, and fine dusty magnetite, while pale green chlorite and an alkali feldspar, though constantly present, are much less plentiful. In No. 1306 at least 50 per cent. of the rock consists of a fine-grained mosaic of quartz grains, while epidote and magnetite are especially abundant, mica in this specimen being of minor importance. No. 1289 is considerably more micaceous, however, and probably contains nearly 50 per cent. of fine muscovite. In all cases the mica is a pale green poorly birefringent variety, apparently similar to that described by Brammall (1921) from slates and phyllites from Bolivia, and identified by him as a slightly impure sericite, containing small amounts of iron and magnesium. The epidote, which in No. 1306 occurs as idioblastic minute prisms as well as in shapeless grains, is a nearly colourless and poorly birefringent type rich in the clinozoisite molecule and poor in iron. Pale blue and brownish tourmaline is a plentiful accessory in No. 1289, where it occurs as perfectly formed unoriented prisms which vary from 0.05 mm. to 0.2 mm. in length, thus greatly exceeding the average grain size of the other minerals present. Small veinlets of clear granular quartz cross the sections in all directions, while in No. 1306 there are a number of clear spots 1 mm. in diameter, consisting entirely of quartz and colourless muscovite.

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* Unless otherwise stated, numbers refer to specimens and sections in the collection of the Geology Department, Otago University.

Lustrous bluish grey phyllites (Nos. 1267, 1290) are exposed continuously along the gorge of the Haast River for a distance of about two miles on each side of its junction with the Wills. They pass gradually southward into the slates of the Upper Mule Valley, while to the north they grade with increasing metamorphism into quartz-albite-muscovite-chlorite-schists (e.g., No. 1307). The strike varies considerably both east and west of the general northerly trend, but north of the Wills it is fairly regular, and lies between 15° and 25° west of north. The dip is always nearly vertical.

No. 1267 (half mile south of Wills River, Haast Gorge). The hand-specimen shows well-defined bands, from 0.25 mm. to 1 mm. in thickness, which are rich alternately in quartz and in micaceous minerals, the quartzose bands being about twice as thick as the micaceous layers. Quartz veinlets, frequently crumpled and folded, cut across the schistosity at all angles. The essential minerals are quartz 50%, feldspar 10%, mica 10%, chlorite 10%, and epidote 20%. The grain size varies in different bands from 0.1 mm. to 0.4 mm., but is fairly constant throughout any particular layer. The quartz is in clear interlocking, sometimes sutured grains, with slightly undulose extinction, while the feldspar, which from its low refractive index is probably albite, is scattered in similar irregular untwined grains through the quartz mosaic. The mica is still the poorly birefringent sericite observed in the slates, but is more perfectly crystallised, and the greenish tint is very faint. The chlorite occurs in ragged flakes faintly pleochroic in pale green tints; the elongation is positive, and strong dispersion combined with very low birefringence produce the Prussian blue anomalous interference tint, when vertical sections are viewed between crossed nicols. It is thus a negative pennine such as Winchell (1927, p. 379) classes as delessite. The epidote is the normal ferriferous type, yellowish in colour, and highly birefringent, and is concentrated mainly in the micaceous layers of the rock. Accessory minerals include abundant small idioblastic prisms of light brown or pale blue tourmaline, a few small prisms of apatite, and rare magnetite grains.

No. 1290 (quarter mile north of Wills River, Haast Gorge) is closely similar, but contains minor actinolite in the form of scattered pale green or almost colourless needles, while one large porphyroblast measuring 3 mm. × 0.3 mm. and several smaller ones, all more or less parallel to the schistosity, were noted.

Several points in the mineral composition of the slates and phyllites described above call for comment. In the first place the abundance of quartz relative to mica is somewhat unusual. For example Dale (1914), in the numerous petrographic descriptions which accompany his account of the slates of the United States, in nearly every case lists the essential minerals in order of abundance as muscovite, quartz, and chlorite, though carbonates, biotite, or carbon may rise to predominance in particular instances. In the rocks under consideration the high quartz or quartz-feldspar content is more noticeable in the phyllites, probably due to the fact that the mineral composition may be estimated with much greater accuracy in these relatively coarse-grained rocks than in the fine-grained slates. It is on this account that the members of the slate-phyllite series are grouped among the quartzo-feldspathic rocks.

A second and more unusual feature is the invariable presence of abundant epidote in all specimens of slate and phyllite examined. The rarity of this mineral as an essential constituent in slates may be gathered from the fact that it is never mentioned, even as an accessory, among the petrographic descriptions of United States slates given by Dale (1914). Similarly it is absent from the slates of Ardennes, which, according to the careful investigations of A. F. Renard (1882), consist of muscovite 38% to 40%, chlorite 6% to 18%, quartz 31% to 45%, haematite 3% to 6%, rutile 1% to 1.5%, together with small amounts of limonite in some instances. In British slates, epidote though not usually plentiful, is by no means unknown, and may sometimes be moderately abundant. For example, Hutchings (1890, p. 267), in discussing the origin of a slate from the vicinity of Newcastle-on-Tyne records the presence of a considerable proportion of epidote which originated by decomposition of clastic biotite, which was itself derived from the breaking down of a two-mica granite. The same writer (Hutchings, 1890, p. 318) suggests that the abundant epidote of some of the Welsh roofing slates may also have originated in this way. He goes on to state (Hutchings, 1890, pp. 316 to 319) that in very fine fireclays the minute shreds of biotite, muscovite, kaolin, and exceedingly fine feldspar waste react with one another under slate-forming conditions to give new mica (sericite) and needles of rutile. On the other hand, in coarser-grained silts where abundant quartz is present, the large flakes of biotite undergo a different type of alteration, and give rise to epidote without the formation of rutile. The presence of abundant quartz and epidote and absence of rutile in the Haast rocks accord well with the conditions outlined by Hutchings; but the relatively low mica content of many of these rocks is difficult to explain on the assumption that the epidote is the result of decomposition of original clastic biotite, since according to Hutchings this reaction also results in the formation of considerable amounts of sericite.

Brammall (1921, pp. 221-223) has outlined a probable mechanism by which accessory epidote may be produced in some slates during the reconstitution of chloritic substances, but it must be admitted that a reaction of this sort could not give rise to such abundance of epidote as has been observed in the present instance.

Two other possible sources of epidote suggest themselves, namely, calcareous or basic igneous material in the original sediment. The presence of considerable amounts of sodic plagioclase and magnetite in some of these rocks appears to favour the latter of these two sources, a view which will be substantiated when the other members of the metamorphic series have been considered. It may be noted that Hutchings (1892, p. 219) states that in some of the ash-slates of the Lake District, epidote, accompanied by chlorite and calcite, has been generated by decomposition of the augite and other ferromagnesian silicates in the original ash.

A third point of interest is the almost universal development of relatively large perfectly idioblastic prisms of tourmaline, which in some cases are oriented parallel to the schistosity. Even though the grade of metamorphism is low and the nearest known outcrop of granite is many miles distant, the presence of this mineral suggests, according to the observations and deductions of Barrell (1921), the contact influence of a subjacent plutonic mass.

(2.) *Quartz-albite-chlorite-schists:* Under this heading are included a large number of schists in which quartz and sodic plagioclase, in variable proportions, are the dominant minerals, while in addition chlorite is always an important constituent. Typically the chlorite is accompanied by fairly plentiful muscovite (Nos. 1292, 1305, 1307), but in some cases (Nos. 1224, 1304, 1311, 1315) it may be almost or completely absent. Epidote and magnetite occur in relatively small but constant amounts, apatite is a universal accessory, while tourmaline and sphene were occasionally noted. The plagioclase, which in some cases may reach as much as 60% of the total composition of the rock, is always almost pure albite in clear, usually untwinned grains, with definitely positive sign and low refractive index. Orthoclase in small amounts was observed in only one section—No. 1224 (Turner, 1930a, p. 185)—but on re-examination of the section this determination is now listed as doubtful. The chlorite is an optically negative pleochroic variety ($X =$ light yellow, $Y = Z =$ deep green, $Z > X$) with small optic axial angle and low birefringence, in most cases giving the anomalous Prussian blue interference tint. Following Winchell (1927, p. 379) this may be classed as negative pennine or delessite. The mica is a typical colourless muscovite, but, as has frequently been observed in muscovites of low-grade metamorphism, the optic axial angle is often small. The epidote includes both iron-rich types with moderate birefringence and distinct pleochroism, and the nearly colourless poorly birefringent variety in which the clinozoisite molecule is greatly predominant.

Rocks of this type are well developed in the Haast Valley from about two miles north of the Wills confluence to two or three miles north of the junction of the Haast and the Burke. Southward they are seen to pass insensibly, through types such as No. 1307, into the phyllites of the Haast Gorge, while with increasing metamorphism they grade northwards into the biotite-bearing schists which outcrop just above the junction of the Haast and its great trbutary, the Landsborough.

The rocks which form the northern end of the Olivine Range east of the peridotite belt are also of this type. Though the valleys of the Arawata and Waiatoto Rivers east of the Olivine Range were not explored, it appears highly probable that a great area of schists, mainly of this type, continues east from the Olivine Range across the Main Divide, and connects with the Lake Wanaka region, where exactly similar schists of the " Central Otago " type are prominently developed.

Although not collected within the area at present under consideration, two specimens of quartz-albite-chlorite-schist from the Main Divide in the vicinity of Mount Aspiring are here recorded, on account of the inaccessibility of the region where they occur, and also since their presence lends some support to the suggestion that the whole of the area between Lake Wanaka and the Olivine Range consists mainly of schists of this type. The specimens in question (Nos. 1304 and 1305) were collected by Mr E. Miller, of Dunedin, to whom the writer's thanks are here expressed.

The following are typical examples of this group of schists:—

No. 1307 (McBride's Bluff, half mile south of Burke Hut, Haast Valley). Megascopically the rock is very similar to the phyllites further south (e.g., No. 1267), but the schistosity is more marked, and the bands of different mineral composition are more sharply defined, while the grain-size is sufficiently coarse to warrant classification as a fine-grained schist rather than a phyllite. Numerous secondary veins of quartz cut across the schistosity. The average composition of the rock as seen in a section perpendicular to the direction of foliation is quartz 35%, albite 25%, delessite 20%, muscovite 15%, epidote 5%, magnetite 1%, together with accessory idioblastic tourmaline. Sharply defined bands from 1 mm. to 3 mm. thick may consist entirely of quartz and a little albite. Others contain delessite and albite in equal proportions as the dominant minerals, while bands especially rich in muscovite and albite are less common. The muscovite is frequently interlaminated with delessite, but may also take the form of simple individual flakes. The epidote occurs as small granular crystals, with which patches of fine magnetite are usually associated.

No. 1292 (stream entering the Haast from the west, one mile below the Burke). The rock is typical of the muscovite-bearing schists of this group, and represents a slightly higher grade of metamorphism than No. 1307, as is indicated by considerably coarser crystallisation and even more perfectly developed schistosity. Albite and somewhat less plentiful quartz, in irregular grains from 0.3 mm. to 0.5 mm. in diameter, together make up about 70% of the rock. The remaining minerals are delessite 20%, and muscovite 10%, frequently interlaminated with one another, and about 3% of colourless clinozoisite which occurs as grains and subidioblastic prismatic crystals (sometimes reaching 0.4 mm. in length), that are always associated with fine grains of magnetite, and usually contain plentiful inclusions of the same mineral.

No. 1305 (summit of Mount French, Mount Aspiring district). The rock is a coarse-grained dark greenish schist composed of quartz 50%, albite 20%, delessite 10%, muscovite 10% to 15%, magnetite 3%, a small amount of pale poorly ferriferous epidote, and tourmaline as a rare accessory. In some parts of the section the grains of quartz and albite often reach from 1 mm. to 1.5 mm. in diameter, while in others they are much smaller and show sutured margins. The albites frequently contain inclusions of fine magnetite as dense patches and parallel bands, with which crystals of epidote may sometimes be associated. Normally the delessite occurs as ragged flakes arranged parallel to the schistosity, but in one part of the section it takes the form of a group of vermicular transversely fibrous inclusions included in a large grain of quartz. A single large crystal of tourmaline with a blue central zone and a brown border was observed, completely surrounded by one of the larger crystals of albite.

No. 1304 (summit of range east of Mount French) is a closely related rock, but is richer in albite, while muscovite is much less plentiful. The crystals of albite are often considerably larger than those of other minerals, and the texture thus approaches closely to porphyroblastic. Colourless, poorly birefringent epidote (Pl. 26, Fig. 1) is relatively abundant (5% to 10% of the total composition of the rock), and occurs as idioblastic prisms which sometimes attain a length of 0.4 mm., and are often associated with the usual dense clouds of magnetite, epidote-magnetite knots of this type frequently being enclosed in the albite porphyroblasts. There are several large grains of brownish sphene.

No. 1311 (200 yards east of peridotite margin, Red Spur, north end of Olivine Range). Megascopically this is a soft greenish rock with very distinct foliation, comparable with many of the schists of Central Otago. The component minerals are quartz 50%, albite 30%, delessite 10% to 15%, epidote 5% to 10%, and muscovite 1%. Alternate bands consist of albite and subsidiary quartz, pure quartz, and delessite, epidote, and albite in approximately equal proportions. The grains are highly irregular and often have sutured margins, while the average grain size is comparatively fine, varying between 0.05 mm. and a maximum of 0.3 mm. in the quartzose bands. The rock is certainly allied to the schist which outcrops two miles south on Martyr Spur, just east of the peridotite margin. This latter rock (No. 1224) has been described previously (Turner, 1930a, p. 185), and differs from No. 1311 mainly in the much greater abundance of yellow epidote, which is concentrated in well-defined bands consisting entirely of epidote and subsidiary chlorite.

(3.) *Corrugated Quartz-albite-muscovite-chlorite-schists:* The rocks included in this group were observed *in situ* in only one locality —on the western bank of the Jackson River, about 300 yards above its junction with the Arawata. This rock (No. 1334) is a thoroughly corrugated schist in which the original schistosity planes have been crumpled into close isoclinal folds. The mineral composition is close to that of the normal quartz-albite-chlorite-schists described above, an approximate estimate giving quartz 60%, plagioclase 30%, chlorite (delessite) 5%, muscovite 5%, together with accessory clinozoisite, magnetite, apatite, and sphene. The grain size varies in different bands from 0.1 mm. to 0.3 mm. The plagioclase is albite (about $Ab_{92}An_8$), and occurs as untwinned grains, somewhat elongated parallel to the schistosity, and usually showing somewhat rounded terminations. The quartz, on the other hand, is in highly irregular grains with perfectly sutured margins and showing undulose extinction. As is usual with schists of this composition, the chlorite and muscovite are often interlaminated.

In a previous paper (Turner, 1930a, p. 199) it was suggested that the Jackson Valley marks the north-easterly continuation of the great shear-zone which is occupied further south by the peridotite intrusion of the Cascade Valley, a view which has since been substantiated by further field evidence. Now the rock just described (No. 1334) actually outcrops at a point on this shear-zone. The structure and texture of the rock themselves point to complete recrystallisation under considerable stress, while the mineral assemblage is also typical of low-grade metamorphism, where shearing stress is the dominating influence and static pressure and temperature are relatively unimportant. In sharp contrast, the rocks which are exposed only a few yards west of the outcrop of corrugated schist are biotite-hornfelses and injection-rocks of distinctly different metamorphic facies, which continue for a distance of at least two miles west of the Jackson Valley.

The view is therefore put forward that the corrugated schist has been formed at a relatively late stage in the metamorphic history of the area, by complete recrystallisation of biotite-hornfels under localised intense stress in the Jackson Valley shear-zone. Since the change involved is one in which an assemblage of minerals formed under relatively high-grade metamorphic conditions has been broken down to a low-grade mineral association, the resulting rock is the product of retrogressive metamorphism, and is a true diaphthorite as originally defined by Becke (1909). In a recent paper on retrogressive metamorphism Eleanora Knopf (1931, p. 27) states that in cases such as the present instance, where the mineralogical adjustment to low-grade conditions of metamorphism has proceeded to completion, the resultant rock is often indistinguishable from a normal low-grade schist—in this case a normal quartz-albite-chlorite-schist—and the field relations alone indicate the true history of the rock. In this connection it may be mentioned that other evidence of retrogressive metamorphism in the Jackson and Cascade Valleys has been found, and some has already been noted (Turner, 1930a, p. 184).

Corrugated quartz-albite-muscovite-chlorite-schists similar to the above, but usually more micaceous (e.g., No. 1341), occur as boulders in Laschelles Creek. They are derived from the Cascade Plateau moraines, and their ultimate source probably lies among the schists of the Olivine Range towards the head-waters of the Cascade River.

(4.) *Quartz-plagioclase-biotite-schists:* Quartz-plagioclase-schists carrying varying amounts of biotite are especially well developed along the south side of the Haast Valley between the Landsborough junction, where they pass gradually into quartz-albite-chlorite-schists, and a point some distance west of Thomas Bluff, where with increasing metamorphism they grade into the quartz-plagioclase-biotite-gneisses of Big Bluff. As in the case of the rocks of the Upper Haast, the strike varies between 20° west of north and 20° east of north, and the dip which is always at high angles appears to be mainly towards the east. Biotite-bearing schists, corresponding to the least metamorphosed of the biotite-schists of the Haast, also occur along the south-eastern side of the Jackson Valley, where they appear to pass eastwards into quartz-albite-chlorite-schists, while on the north-west they are sharply limited by the Cascade-Jackson Valley

Fault. Rocks of this type are plentifully represented among the boulders of Turnley Creek and the Jackson itself.

The rocks of this group are invariably highly schistose with sharply marked thin layers alternately rich in mica and the light-coloured constituents. The most abundant minerals are quartz, plagioclase, biotite, and muscovite, but the essential petrographic feature of all members of this series is the presence of biotite, which now wholly or partly takes the place of the chlorite of rocks of lower metamorphic grade.

The feldspar is plagioclase, into the composition of which the anorthite molecule now perceptibly enters as the grade of metamorphism advances. In one abnormal instance (No. 1283) nearly pure albite was noted, but usually the anorthite-content reaches about 7% or 8% in the less metamorphosed members of the series, while in those rocks which approach the quartz-plagioclase-biotite-gneisses in composition and structure it may rise to between 15% and 30%.

A mineral of the epidote group is nearly always present, and occasionally may make up as much as 10% of the total mineralogical composition, while in one instance it reaches about 20%. Magnetite is a constant accessory, while apatite and tourmaline may also occur.

No. 1325 (boulders, Turnley Creek, Jackson Valley). In hand-specimen the rock is a grey schist closely similar to the quartz-albite-chlorite-schists described above, but with scattered spots of golden brown biotite showing up on the schistosity planes. The constituent minerals are quartz 30% to 40%, plagioclase 30% to 40%, muscovite 10%, epidote 10%, biotite 5%, and chlorite 5%. The grain-size averages 0.1 mm. to 0.2 mm. The water-clear irregular grains of albite have a refractive index lower than either that of Canada balsam or that for the ordinary ray in quartz, while the optic sign is positive, and the extinction angle X to 001 cleavage in sections perpendicular to the acute bisectrix is about 18°. The anorthite content is thus not greater than 5%. The muscovite is faintly pleochroic (Y = Z = pale green, X = colourless), with a relatively small optic axial angle. Biotite, with strong pleochroism from pale yellowish to deep yellowish brown, occurs as scattered irregular porphyroblastic knots which may reach 2 mm. or 3 mm. in average dimensions, and also as small wisps associated with the sparsely distributed flakes of pale green chlorite. The epidote takes the form of small colourless or yellowish grains, with fairly low birefringence indicating a low percentage of iron. Accessory sphene is also present.

No. 1309 (boulders, Turnley Creek, Jackson Valley) is a somewhat similar rock representing a slightly higher grade of metamorphism, and hence more typical of the biotite-bearing schists than No. 1325 described above. The biotite is better crystallised and more plentiful, and is strongly pleochroic from pale yellowish to deep sepia brown, while the anorthite content in the albite is about 7% or 8%. The latter mineral tends to form small porphyroblasts a little larger than the surrounding grains of quartz.

No. 1282 (Thomas Bluff, Haast River). The rock is a highly fissile, finely banded schist, and may be taken as typical of the great series of biotite-schists which outcrop over a distance of some 15 miles along the south side of the Haast Valley west of the Landsborough junction. In section the schistose texture is marked by sharply defined banding, and by elongation of the quartz grains and orientation of the micas parallel to the foliation. Grains of quartz averaging about 2 mm. in diameter, with sutured margins and pronounced undulose extinction, make up 50% of the rock. The plagioclase (about 10% of the total composition) is albite-oligoclase, $Ab_{90}An_{10}$. Strongly pleochroic biotite (X = pale yellow, Y = Z = deep reddish brown) is abundantly developed as ragged flakes up to 1.5 mm. long, which constitute 25% of the rock, while small oriented ragged flakes of muscovite are also abundant. Epidote, fine-grained magnetite, apatite, and rare prisms of brown tourmaline are the accessory minerals.

Nos. 1286 and 1288, which were collected from large masses and boulders in the bed of Douglas Creek, Haast Valley, are of interest in that they show the effects of somewhat more intense metamorphism than do the other biotite-schists of this part of the Haast Valley, and may therefore be regarded as intermediate between the biotite-schists and the biotite-gneisses to be described in a later section. Megascopically both rocks resemble the normal quartz-plagioclase-biotite-schists in the development of sharply defined, thin, alternately micaceous, and quartzose bands, but the grain is somewhat coarser and the rocks are noticeably more coherent than is usual in the biotite-bearing schists. On the other hand, the grain is much finer than in the coarse biotite-gneisses such as those of Big Bluff, Haast Valley.

No. 1286 consists of quartz 50%, muscovite 30%, biotite 15%, plagioclase 5%, and accessory apatite, magnetite, and tiny prisms of zircon. The quartz is in highly irregular, interlocking sutured grains from 0.1 mm. to 1 mm. in diameter, with marked undulose extinction. The plagioclase occurs in scattered, sometimes twinned grains with a maximum refractive index above that of the ordinary ray in quartz, while the maximum extinction angle is 6° to the albite twinning plane in sections perpendicular to 010. The sign is indeterminate since the optic axial angle approaches 90°. The variety is therefore oligoclase, with composition approximately $Ab_{85}An_{15}$. Muscovite and deep reddish brown biotite both occur in long ragged flakes oriented parallel to the schistosity.

In No. 1288 (Pl. 26, Fig. 2) the component minerals are plagioclase 40%, quartz 20%, biotite 15%, chlorite 15%, clinozoisite 10%, magnetite 1%, and accessory tourmaline. The grain is distinctly coarse, the average grain-size being 0.5 mm., while some crystals, notably the biotites, may attain as much as 2 mm. in diameter. The feldspar occurs in irregular grains, sometimes showing polysynthetic twinning, optically negative, with a maximum extinction angle of 17° to the albite twinning plane in sections perpendicular to 010. It is thus an acid andesine, about $Ab_{68}An_{32}$. It frequently contains finely vermicular quartz, which evidently represents an early stage in the development of the myrmekitic intergrowths that are so well displayed in many of the coarsely crystalline composite biotite-gneisses (see p. 202). An unusual feature is abundance of pale green nearly isotropic chlorite. The epidote mineral is mainly very poorly birefringent clinozoisite, as idioblastic prisms 0.3 mm. × 0.1 mm., which sometimes grade into poorly ferriferous epidote, the birefringence of which reaches 0.25. Idioblastic prisms of brown tourmaline are unusually plentiful in some parts of the section.

(5.) *Biotite-hornfelses:* In the previous paper already referred to (Turner, 1930a, pp. 174-180) a number of hornfelses, contact schists, hornfelsic paragneisses, and composite gneisses were grouped together as the " Older Metamorphic Series " of the Cascade Valley, and their distribution was described as fully as was then possible. Further field work has since shown that these rocks, except where mantled by small areas of Tertiary and Pleistocene deposits, underlie the whole of the coastal area between the Hope and Arawata Rivers north-west of the Cascade-Jackson Valley fault, while specimens supplied to the writer by Mr Eric James, of Makarora, indicate that rocks of this type also extend considerably south of the Hope River itself. North of the Arawata they reappear on the coast just south of Okuru at Mussel Point, where they outcrop from beneath the Quaternary alluvial and beach deposits, which constitute the coastal plain between Jackson's Bay and the Haast. Gneisses belonging to this group also are exposed in the large bush-covered knoll about one mile south of Mr J. Cron's homestead at the mouth of the Haast River, and again at Big Bluff some six miles inland.

Though the hornfelses and gneisses of this area are alike, in that all show marked effects of contact metamorphism by a subjacent mass of granite (see p. 204), rapid local variation in the relative importance during metamorphism, of such agents as heat, stress, injected igneous material, and magmatic emanations, has resulted in the production of a variety of distinct petrographic types. These are so intimately associated and grade so rapidly into one another that it is impossible to represent them separately upon the map.

The most widespread of these types is biotite-hornfels, which occurs very abundantly from Mussel Point southwards, though not yet observed among the rocks of the Haast Valley. The rocks are typically greenish-grey to brown in colour, fine-grained or less commonly of medium grain, without visible foliation, and show beneath the microscope the granoblastic texture typical of the hornfels group. The essential constituents of the unaltered rock are quartz, biotite, and plagioclase (albite-oligoclase to acid andesine in most cases), while muscovite is also present, usually to a minor extent only. Partial alteration of the biotite frequently gives rise to abundant chlorite, sphene, and sometimes epidote, while the feldspars may be partially or completely replaced by sericitic mica. With increasing development of these secondary minerals the biotite-hornfelses pass into chlorite-hornfelses, the origin of which will be discussed in the section dealing with rocks of that class.

The following are descriptions of typical biotite-hornfelses:—

No. 1329 (Arawata Valley, 1½ miles west of mouth of Jackson River). Macroscopically this is a medium-grained hornfelsic rock with scattered lustrous porphyroblastic crystals of muscovite from 3 mm. to 5 mm. in diameter, plainly visible on the broken surface. The rock, which is normally brown in colour, is irregularly blotched with lenses and patches of a light green colour where the biotite has been replaced by chlorite. The constituent minerals are quartz 50%, biotite and chlorite 20%, feldspar 25%, muscovite 5%, and sphene, apatite, magnetite, and a little epidote as accessories. The texture is granoblastic, the average grain size of the three essential components being about 0.2 mm. The quartz is in highly irregular sutured grains which show undulose extinction. The feldspar occurs as xenoblastic untwinned or rarely polysynthetically twinned grains, the optical properties of which indicate that it is albite carrying about 5% to 7% of anorthite. In a few cases it is almost unaltered, but usually it is partially or even wholly replaced by aggregates of fine sericite. The biotite is strongly pleochroic from pale yellowish to sepia brown, and shows all stages from incipient to complete replacement by a chlorite which is uniaxial, optically negative, and very poorly birefringent, thus corresponding to negative pennine or delessite. Finely granular sphene, representing the titanium content of the original biotite, is usually plentifully associated with these chlorite pseudomorphs. In addition to the secondary sericite there are several large highly irregular porphyroblasts of clear primary muscovite which enclose numerous grains of quartz to give a typical sieve-structure. Calcite occurs as occasional granular patches 0.1 mm. to 0.5 mm. in diameter, and is probably to be regarded as a secondary product developed during sericitisation of the plagioclase. The most plentiful accessory mineral is sphene, which was observed as large irregular primary grains in addition to the secondary sphene derived from biotite, while apatite and magnetite are somewhat less common. Epidote, also a decomposition product of biotite, was noted in one or two instances.

No. 1328, from the same locality as No. 1329, is a very similar though somewhat finer-grained rock, in which the alteration of biotite and feldspar is more complete and has proceeded along somewhat different lines from those followed in the previous specimen. The rock consists of a mosaic of clear quartz grains, among which numerous aggregates of biotite, sericite, epidote, and finely granular sphene are interspersed. The biotite occurs as ragged flakes, each of which typically is set in a mass of fine sericite mica containing plentiful grains of poorly birefringent epidote and pale yellow sphene, while magnetite and chlorite are occasionally present. The relation of the biotite to the sericite, and the presence of sphene associated with the latter mineral, suggest that the biotite is a primary product of hornfelsing, while the sphene and part at least of the sericite are secondary products derived from it. Though feldspar is absent from this section, its former presence is indicated by abundant clinozoisitic epidote associated with the sericite, much of which may thus have been derived from original plagioclase. It is therefore concluded that the aggregates of sericite, epidote, and sphene are the result of simultaneous alteration of biotite and sodic plagioclase during a late stage in the metamorphic cycle, subsequently to the crystallisation of a quartz-biotite-plagioclase-hornfels at an earlier stage.

The hornfelses from the vicinity of the bridge across Martyr Gorge (Nos. 1200 and 1201) and from alongside the track about one mile south-west of this locality (Nos. 1204 to 1207) have already been described (Turner, 1930a, pp. 175, 176), and little need be added with reference to these rocks. They are considerably coarser in grain than those from the Arawata Valley, and at the second exposure mentioned above are so closely veined with narrow dykes of granite and granite-pegmatite that the whole composite mass might be described as a coarse-scale lit-par-lit gneiss. The features which are characteristic of the injection-gneisses described later in this paper are confined, however, to narrow zones from 1 cm. to 5 cm. wide bordering the intrusive veins, while the intervening rock remains typically hornfelsic. It therefore seems advisable in comparing these rocks with those from other localities such as the Arawata Valley to consider the whole mass as a normal hornfels invaded by unusually plentiful granitic veins, rather than as a composite coarsely-banded gneiss.

Re-examination of the original sections and examination of fresh material has necessitated certain corrections and additions to the earlier descriptions cited above. The most important correction is with reference to the feldspars of the hornfelses, which were originally described as andesine, accompanied by a somewhat less amount of orthoclase. Though sericitisation renders determination of the optical properties somewhat difficult, it is safe to say that orthoclase could not be determined with certainty in any of these rocks, and is probably altogether absent. The plagioclase is usually oligoclase, but sometimes may be as basic as acid andesine, and varies between about $Ab_{90}An_{10}$ and $Ab_{70}An_{30}$ (No. 1204). As in the hornfelses from the Arawata Valley, the alteration product, which obscures most of the crystals of feldspar to a greater or less extent, is mainly sericite, and not kaolin as was previously stated. When chloritisation of the biotite has taken place, finely granular sphene and less commonly magnetite accompany the chlorite (e.g., Nos. 1200, 1201).

Biotite-hornfelses are plentiful among the boulders of Laschelles Creek, Cascade Valley. These are partly derived from the great series of conglomerates which underlie the Pleistocene moraines of the Cascade Plateau (Turner, 1930b, pp. 527-529), and partly from the large area of hornfelsic rocks which is drained by the upper portion of the creek itself. A general description of several representative specimens (Nos. 1215 to 1218) has already been given (Turner, 1930a, pp. 179, 180).

No. 1342 (boulder, Laschelles Creek) is typical of a porphyroblastic type of hornfels, which, although common at this locality, was not formerly recorded. Macroscopically the rock is a hard greenish-brown fine-grained hornfels mottled with small but conspicuous patches of white mica. The mineral composition is approximately quartz 40%, feldspar 25%, biotite 20% to 25%, muscovite 10% to 15%, and small grains of accessory magnetite, epidote, tourmaline, apatite, and sphene. Quartz, biotite, and feldspar constitute an equigranular mosaic throughout which are scattered large, highly irregular unoriented porphyroblasts of muscovite containing a great number of included grains of quartz, and thus showing perfect sieve-structure. Biotite, magnetite, and epidote may also occur as rare inclusions in the muscovites in some cases. The biotite is the usual reddish brown strongly pleochroic variety, and is unaltered. The feldspar includes equal quantities of microcline and plagioclase. The former occurs as water-clear often irregular crystals which frequently show the characteristic twinning of this mineral, while the plagioclase—medium oligoclase about $Ab_{80}An_{20}$—takes the form of angular or subangular untwinned grains which usually show incipient alteration to fine sericite.

Two main types of biotite-hornfels with intermediate gradations may thus be recognised among these rocks from Laschelles Creek. The more usual variety (Nos. 1215 to 1217) consists mainly of a granoblastic mosaic of quartz and biotite with minor muscovite, feldspar being absent or present in small amounts only. The presence of small quantities of labradorite and green hornblende in No. 1217 is an unusual feature worthy of emphasis. In the second type (e.g., No. 1342 just described) both plagioclase and microcline are present in considerable quantity in addition to the usual quartz and biotite, while large porphyroblasts of muscovite with perfect sieve-structure impart a distinctive appearance to the rock both in section and in hand specimen.

Biotite-hornfelses have also been described from the northern portion of the Hope-Blue River Range. A mineral provisionally identified as prismatine (Turner, 1930a, p. 179) was noted in a specimen (No. 1214) from this locality.

The origin of the biotite-hornfelses is intimately connected with that of the other metamorphic rocks with which they are associated, and its consideration will be left till a later section, when the sequence of events in the metamorphism of the whole area will be discussed. It is here sufficient to state that in texture they are typical hornfelses, the recrystallisation of which was governed mainly by high temperature, the influence of directed stress being negligible. They are the contact-metamorphic equivalents of original sediments. Comparison with associated gneisses and schists suggests that coarse porphyroblastic muscovite and interstitial microcline, when present, may have been developed by the action of percolating magmatic aqueous solutions rich in potash, emanating from the subjacent mass of granite magma to the presence of which the hornfelsing was itself due. Tattam (1929, p. 17) suggests a somewhat similar mode of origin for porphyroblastic muscovite of the "schistose hornfelses" described by him from North-east Victoria.

(6.) *Chlorite-hornfelses:* In almost every locality where the biotite-hornfelses are exposed they show patches of variable extent, where the normal brownish-coloured rock has undergone local alteration to light green chlorite-hornfels. This feature is well illustrated along the track between the Martyr-Jackson Saddle and Martyr Bridge, and again about one mile south-west of the bridge itself. Though the resultant rock is usually best described as normal biotite-hornfels mottled with greenish altered patches, in some cases, especially when the original rock was fine-grained, alteration is complete and the whole mass now consists of chlorite-hornfels.

The essential features of these rocks are granoblastic texture upon which the effects of more or less severe shattering have been superimposed, and the presence of chlorite and sericite replacing original biotite and feldspar (presumably plagioclase).

No. 1354 (boulder, Martyr Creek, 400 yards below gorge) is a typical fine-grained greenish chlorite-hornfels, crossed by highly irregular veinlets of secondary quartz about 1 mm. wide, which probably mark shear and fracture planes. The essential constituents are quartz 50%, chlorite 35%, and white mica 15%. The quartz is mostly in grains from 0.2 mm. to 0.4 mm. in diameter, some of which display incipient breaking down to smaller grains as a result of crushing. Constant features of the larger grains are undulose extinction and the development of bands of minute inclusions which are roughly parallel throughout the section. The chlorite is delessite (negative pennine), with strong pleochroism from fairly deep green (Y and Z) to light greenish yellow (X). It forms subidioblastic flakes which always contain numerous inclusions of granular sphene, and occasionally enclose grains of epidote or magnetite. As in the partially altered biotite-hornfelses described in the previous section, the chlorite obviously replaces biotite, the titanium content of which is now represented by the enclosed sphene. The white mica is mostly sericite in the form of patches or aggregates of small irregular flakes derived from feldspar, remnants of which may still be observed in rare cases. There is also a subsidiary amount of muscovite as relatively large, more regular crystals, comparable with the primary muscovite of the unaltered biotite-hornfelses. Very rarely grains of clear microcline were also noted. Coarse irregular grains of apatite and small idioblastic crystals of colourless to pale yellow tourmaline are plentiful accessories.

No. 1346 (boulder, Laschelles Creek, Cascade Valley) is a fine-grained green hornfels, with numerous tiny ramifying veinlets and streaks consisting largely of quartz and calcite. In section the rock is somewhat similar to that just described, but the effects of crushing are much more marked, so that a cataclastic texture has been developed. The grains of quartz, originally about 0.3 mm. in diameter, have been intensely shattered, so that residual angular grains of this dimension are now set in a crushed matrix consisting of small grains of quartz, along with pale green chlorite (delessite) and flaky sericite, respectively derived from biotite and feldspar. Granular sphene is everywhere included in the chlorite, while in some parts of the section occasional relics of biotite still persist. Irregularly disposed planes of intense shearing are marked by the presence of finely granular epidote, crushed quartz, and irregular streaks of calcite, the latter mineral probably representing the calcium content of now sericitised plagioclase.

No. 1218 (boulder, Laschelles Creek), described in a previous paper (Turner, 1930a, p. 180), is a chlorite-hornfels derived from an originally biotite-bearing rock containing occasional porphyroblastic sieve-muscovites and a small amount of clear microcline, both of which remain unaltered. The titanium of the biotite has given rise to the perfect development of needles of sagenetic rutile in the chlorite pseudomorphs which have now replaced it. Grains of sphene are fairly plentiful throughout the section.

The chlorite-hornfelses are believed to be the product of retrogressive metamorphism of rocks of the biotite-hornfels group, the chief mineralogical changes being chloritisation of biotite and sericitisation of feldspar, with the production of minor amounts of epidote and calcite in some cases.

In dealing with the mineralogical criteria of retrogressive metamorphism (diaphthoresis of Becke), Eleanora Knopf (1931, p. 22) emphasises the presence of sagenetic rutile in chlorite as a sure indication of its origin from biotite. The universal presence of inclusions of sphene in the chlorites of the chlorite-hornfelses under consideration doubtless has similar significance. Furthermore the transition of biotite to chlorite is often actually observable in the associated biotite-hornfelses, and the negative pennine or delessite so produced agrees well in its optical properties with the relatively dark-coloured strongly negative chlorite which Goldschmidt (1920, p. 45) considers to be indicative of diaphthoresis in the rocks of Stavanger district, southern Norway (E. Knopf, 1931, pp. 20, 21). Sericitisation of plagioclase and accompanying formation of clinozoisitic epidote are changes familiar enough in the low-grade metamorphism of igneous rocks, and have also been noted as retrogressive processes by Kieslinger (1926). (E. Knopf, 1931, p. 22.)

The mechanical effects of crushing and shearing displayed to some extent by all the chlorite-hornfelses examined, also lend strong support to the view that the mineralogical peculiarities of these rocks are due to retrogressive metamorphism. In this connection the following statements of Eleanora Knopf (1931, p. 7) may be quoted: " The existence of diaphthoresis implies that the rock in question has undergone, since the imprint of the earlier metamorphism (in this case hornfelsing), an active deformation of the sort to produce inner differential movements, that in some way . . . promote a molecular interchange and rearrangement that results in diaphthoresis." " If adjustment to the new pressure-temperature field is to take place the instigating force or trigger of the reaction must be furnished by a strong differential movement of the constituent parts before or together with the diaphthoresis."

In view of the above statements it is of special significance that the chlorite-hornfelses appear to attain a maximum development in the vicinity of the great shear-zone already referred to, along the line of the middle part of the Cascade and the Jackson Valleys. The diaphthoresis of the original biotite-hornfelses is therefore believed to have been instigated by shearing movements which affected these rocks at a late stage in the metamorphic cycle, subsequently to the hornfelsing, and which were especially powerful along the Cascade-Jackson Valley shear-zone.

(7.) *Biotite-andalusite-hornfels:* Andalusite is extremely rare in the metamorphic rocks of the Cascade-Arawata area, and in the previous paper cited (Turner, 1930a, p. 179) was recorded in only one specimen, a banded gneiss (No. 1212) of the hornfelsic paragneiss group. A quartz-biotite-oligoclase-hornfels (No. 1343), of which this mineral appears to have originally been a constituent, has since been collected from a boulder in Laschelles Creek, Cascade Valley.

This rock is a fine-grained grey hornfels consisting of quartz 50%, acid oligoclase 25%, biotite 20%, together with about 5% of secondary sericite, and accessory iron-ore, apatite, and epidote. The grains of quartz and oligoclase are mostly about 0.3 mm. in diameter, but there are also interstitial smaller grains resulting from incipient crushing. The biotite resembles that of the basic amphibole-schists in its strong pleochroism from pale yellow to very deep greenish brown, a sharp contrast with the reddish brown biotite which is almost universal in the biotite-hornfelses. The flakes are also unusually small (0.05 mm. to 0.1 mm. wide), and some show the first stages of alteration to deep green chlorite. Finely fibrous sericite occurs as sharply defined prismatic pseudomorphs reaching 1 mm. in length, with numerous rounded inclusions of quartz. This last feature, together with the prismatic outline, suggest that the original mineral might well have been andalusite, especially in view of the well-known tendency for this mineral to be replaced by " shimmer-aggregates " consisting largely of white mica. The alteration was probably brought about by retrogressive metamorphism, to which the partial replacement of biotite by chlorite and slight sericitisation of the oligoclase are no doubt also due.

(8.) *Hornfelsic Paragneisses:* The hornfelsic paragneisses are best developed *in situ* in the steep gorge of the stream which drains south-westward into Martyr Creek just below the ford where the track crosses that stream, 1½ miles above its junction with the Cascade River. Specimens 1208, 1349, and 1355 are from this locality. Boulders of this type are also plentiful in the bed of Colin Creek, which drains the north-western face of the Hope-Blue River Range, and are occasionally met with among the gravels brought down by Laschelles Creek.

Four characteristic features render these rocks conspicuous in the field, and equally distinctive when examined beneath the microscope. Though massive and compact, they always show very regular sharply-defined banding, due to alternation of fine and coarse texture, or differences in mineralogical composition of adjacent bands. Individual layers of the banded gneiss vary from 1 mm. to 100 mm. in thickness, but the thickness of a particular type of band remains fairly constant in any one specimen. The second characteristic feature is a general lack of schistosity due to more or less granoblastic texture, so that the rock breaks beneath the hammer in much the same fashion as a normal hornfels. In some instances, however (e.g., No. 1349), there may be marked fissility due to a tendency towards parallel orientation of the flakes of biotite and muscovite, in which case there is gradual transition towards micaceous schists, such as No. 1209 previously described (Turner, 1930b, pp. 177, 178). The third peculiarity of the hornfelsic paragneisses is a constant tendency for the biotite to crystallise as large usually unoriented porphyroblasts about 1 mm. or 2 mm. in diameter, especially in those bands which appear macroscopically to possess a coarse texture. Typically these large biotites enclose numerous inclusions of quartz, feldspar, and occasionally muscovite, and thus exhibit perfect sieve-structure. Finally muscovite is usually abundant in small well-formed flakes which only occasionally show parallel orientation.

The most abundant minerals are quartz, biotite, and muscovite, with variable but usually minor quantities of acid plagioclase, and accessory apatite, brown tourmaline, and sometimes magnetite. Andalusite is moderately plentiful in one case (Nos. 1211, 1212). As in all the typical rocks of the Quartzo-feldspathic Group, quartz and feldspar combined normally predominate over the micas, though particular bands of otherwise quartzo-feldspathic rocks may often contain very plentiful biotite and muscovite. With increasing development of these mica-rich bands, such rocks show gradual transition into the banded mica-schists of the Micaceous Group.

No. 1208 may be taken as a typical example of these banded paragneisses. The bands, alternately coarse and fine, are about 30 mm. in thickness, and are very sharply defined. In the fine bands (No. 1208a) the composition is quartz 40%, untwinned acid oligoclase 25%, biotite 25%, and muscovite 10%, with brown tourmaline and apatite as plentiful accessories. The quartz, feldspar, and muscovite constitute a mosaic of unoriented grains and flakes averaging about 0.2 mm. or 0.3 mm. in diameter. Ragged porphyroblasts of deep brown strongly pleochroic biotite (0.5 mm. to 1 mm.) occur throughout, and often show incipient sieve-structure due to the presence of included grains of quartz and less commonly flakes of muscovite. These porphyroblasts exhibit some degree of uniform arrangement parallel to the banding, in marked contrast with the totally unoriented condition of the surrounding crystals of muscovite. The coarser bands (No. 1208b) are surprisingly similar to the finer layers, the essential difference being the greater size of the biotite porphyroblasts, which now reach 1.5 mm. in diameter, and have very perfect sieve-structure. The surrounding mosaic is identical with that of the finer bands, except that quartz and muscovite are more plentiful while feldspar is present to the extent of about 5% or 10% only. Throughout the whole rock the effects of stress may be seen in the undulose extinction of grains of quartz and feldspar, and occasional distortion of crystals of biotite.

No. 1349 (Pl. 27, Fig. 7), representing a thick, fissile, coarse band collected a few yards distant from the specimen just described, is a closely similar rock. Most of the crystals of both biotite and muscovite, however, are arranged in approximately parallel position, with the 001 cleavage parallel to the direction of banding, thus producing the marked fissility already noted. An interesting textural feature, which indeed is commonly observable in the hornfelsic gneisses of the porphyroblastic type, is the equidimensional form assumed by the large biotites, which completely lack any trace of the normal flattening parallel to 001 (Pl. 27, Fig. 7). The small crystals of muscovite are nevertheless normal in this respect, and are noticeably elongated at right angles to the vertical crystallographic axis.

No. 1345 (boulder, Laschelles Creek) was collected from a coarse-grained non-schistose band which proved on sectioning to be highly micaceous, the assemblage of minerals being biotite 35%, muscovite 40%, quartz 15%, and acid oligoclase 10%. The biotite has the usual intense pleochroism from pale yellow to deep reddish brown, and occurs as large porphyroblasts 1 mm. or 1.5 mm. in diameter, enclosing numerous rounded grains of quartz and feldspar and very rarely flakes of muscovite (Pl. 27, Fig. 8). The surrounding groundmass is a mosaic of small unoriented crystals (about 0.05 mm.) of muscovite, quartz, and feldspar. Occasional grains of magnetite and epidote are associated with the biotite.

In a closely similar rock (S.W. 30, p. 217, Auckland University College collection) from the same locality the crystals of biotite are partially or completely replaced by pale green delessitic chlorite with small inclusions of sphene or sometimes of epidote. An unusual feature is the presence of a number of large unoriented porphyroblasts of chlorite with sieve-structure. It is distinctly pleochroic from rather pale green (parallel to X and Y) to almost colourless (Z), with relatively high refractive index (slightly higher than that of the biotite), very weak double refraction, strong dispersion, and frequently developed polysynthetic twinning. The crystals are elongated negatively, the optic sign is positive, and the optic axial angle is small. Rounded inclusions of quartz are numerous, and in each crystal are almost entirely restricted to a central hour-glass-shaped zone, the long axis of which is parallel to 001, much as described and figured by Simpson (1915, p. 74) in the case of chloritoid from Yampi Sound, Western Australia. The mineral thus closely resembles chloritoid, from which it differs only in its too low refractive index and weak absorption tints.

No. 1355 (boulder, Martyr Ford) is a very regularly banded rock consisting of alternating dark bands 0.5 mm. to 1 mm. in thickness and light-coloured bands from 2 mm. to 5 mm. thick. The average composition of the rock is quartz 50%, biotite 25%, oligoclase 15%, and muscovite 10%, with tourmaline and apatite as accessories. The oligoclase is of medium composition, about $Ab_{80}An_{20}$, and occurs in usually untwinned grains often partly replaced by sericite. Complete or partial alteration of biotite to delessite and subsidiary magnetite, as a result of retrogressive metamorphism at a late stage, may frequently be observed, the process being confined to irregular patches which bear no relation to the banding. The usual porphyroblastic development of biotite is totally lacking. In the lighter bands the four main constituents build up a granoblastic mosaic of unoriented grains in which biotite is present to the extent of about 10%, but in the darker bands the proportion of biotite rises to between 50% and 60% of the total composition, and the flakes are relatively large (0.5 mm. to 1 mm. in diameter). The distinctive features of this rock, which is a widely distributed type, are the unusually thin bands, complete lack of orientation of any of the constituents, and absence of porphyroblastic biotite with sieve-structure.

In considering the origin of the hornfelsic paragneisses, the prominent and regular banding combined with total lack of schistosity, or at most only moderate fissility, requires explanation. The banding appears comparable with the well-known colour-banding of the Moine Gneisses of Scotland, which is invariably commented upon in the numerous descriptions of those rocks in various memoirs of the Scottish Geological Survey. This feature of the Moine rocks is due to concentration of biotite or sometimes magnetite in particular layers, and has been taken by most writers on the subject (e.g., Read, 1926, p. 113) as indicative of a sedimentary origin for the rocks in question. Garnetiferous sedimentary gneisses, which are regularly banded on a coarse scale due to differences in composition of the original strata, have been described from the pre-Cambrian rocks of North America by several writers (e.g., Adams, 1895, p. 64; Adams and Barlow, 1910, pp. 173-191; Bruce and Matheson, 1930, pp. 119-132). More recently Tilley (1921, pp. 251-259) has given a comprehensive account of certain regularly banded garnetiferous paragneisses from South Australia, in some types of which the individual bands are less than ¼in. in thickness. Commenting upon the origin of this feature Dr. Tilley states that it is " essentially a structure arising from initial differences of composition in the original sediments " (Tilley, 1921, p. 252).

By analogy it is therefore concluded that the banded structure of the Cascade Valley rocks is the direct result of variation in composition and texture throughout an initially finely stratified series of sediments. This assumption explains such petrological features as the restriction of andalusite in Nos. 1211 and 1212 to one set of bands, which doubtless represent laminae originally relatively rich in argillaceous material.

The textural features of the gneisses of this group plainly indicate that the dominating agency which controlled their crystallisation was high temperature, which was doubtless due, judging from the mineralogical similarities between the gneisses and associated biotite-hornfelses, to the same granite invasion which was also responsible for the hornfelsing of the latter rocks. As a result of localised stress in addition to high temperature, some degree of schistosity was imposed upon the gneisses in certain instances.

Local chloritisation of biotite and sericitisation of plagioclase, accompanied by minor development of strain effects, are attributed to incipient retrogressive metamorphism at a later stage.

(9.) *Composite Gneisses:* Under this heading are included certain coarse-grained, usually well-foliated rocks, which have originated as a contact phase of the sedimentary hornfelses, schists, and paragneisses, as a result of widespread invasion of these rocks by numerous small dykes of granite and granite-pegmatite. The term is applied only to rocks the structure and chemical composition of which have been considerably modified by accession of material introduced from the intrusive veins.

In the south-west portion of the map gneisses of this type are plentifully developed as narrow fringing bands, bordering the pegmatite veins which here invade hornfelses and hornfelsic paragneisses. In spite of their frequent development their total volume is relatively small in comparison with that of the normal invaded rock, since the individual bands of composite gneiss are usually only 5 cm. to 25 cm. in thickness. They are especially well shown, however, along the track at the south end of the bridge across the gorge of Martyr Creek, where bands of coarse gneiss several feet in width have been formed along the pegmatite-hornfels contacts. Narrow bands of gneiss derived from the biotite-hornfelses are also well exposed about one mile south-west of this locality, and again at intervals along the southern bank of the Arawata River for a distance of over one mile westward from the Jackson-Arawata confluence. These rocks have also been developed by contact alteration of the hornfelsic paragneisses in localities where the latter have suffered invasion by pegmatites.

In all the above cases restriction of the composite gneisses to the immediate vicinity of the intrusive dykes indicates clearly that their formation was governed by intrusion of pegmatites into rocks already completely recrystallised (as hornfelses or hornfelsic paragneisses) under high-temperature conditions. The field relations necessitate that the period of pegmatitic injection and gneiss formation was subsequent to the period of hornfelsing.

In the northern portion of the map gneisses of somewhat similar type are abundantly developed on the eastern flank of a heavily bushed knoll about one mile south of Mr J. Cron's homestead near the mouth of the Haast River, and again at Big Bluff on the south side of the Haast Valley, some six miles inland. The gneisses in this area are not confined to narrow bands bordering pegmatite intrusions, but constitute an extensive mass of rocks, which appear to have originated by very intense dynamo-thermal metamorphism of quartzo-feldspathic sediments, aided to a minor extent by widespread permeation by magmatic solutions, probably during the period of pegmatite injection. The rocks in question are relatively well foliated compared with the hornfelsic rocks further south, and this fact perhaps accounts for their much more complete permeation in the manner indicated above. The mineralogical changes induced by the pegmatitic fluids are not nearly so intense as in the gneisses from the southern portion of the map, and the amount of introduced material cannot be large. Eastward from Big Bluff there is perfect transition from gneisses showing minor effects of pegmatite injection, to the unmodified quartz-plagioclase-biotite-schists which occur so plentifully along the southern bank of the Haast from this point to the Landsborough.

Numerous descriptions of more or less closely similar gneisses of composite origin are to be found in the literature dealing with metamorphic rocks, but the nomenclature of such rocks is by no means uniform. K. Sugi (1930, pp. 75-96) uses the term " injection-rocks " to cover a variety of gneisses of this type from the Tsukuba district of Japan, where sediments of the Chichibu Series have been invaded and strongly metamorphosed by a granite batholith. This writer (Sugi, 1930, pp. 75, 76) states that two types of injection, not always clearly separable, have played an important part in the genesis of these rocks, namely, lit-par-lit injection, and [illegible] by magmatic material without resultant banding. On the other hand, contact gneisses of similar origin, in which recrystallisation was accompanied by thorough permeation by magmatic solutions, have recently been described by C. M. Tattam (1929, pp. 17, 18) as " schistose hornfelses."

In the rocks at present under consideration the dominant genetic process appears to have been a thorough permeation of the whole rock by magmatic solutions under conditions of intense metamorphism, rather than lit-par-lit injection of individual layers of granitic material, though at the actual pegmatite-gneiss contacts this latter process has certainly operated to a minor extent. It is therefore proposed to include the rocks in question under the general heading of " composite gneisses "—a term which indicates origin by admixture of sedimentary and igneous material, without implying whether the introduction of magmatic matter was effected by general impregnation or by actual injection of definite layers. According to Holmes (1920, p. 66) this expression was introduced by Professor Grenville Cole in 1902 to include " gneisses produced by the intimate association, with or without molecular intermixture, of two different materials, the one (generally a granitic magma) having been injected into the other." Composite gneisses as defined above would therefore include both purely lit-par-lit gneisses (e.g., Cole, 1916) and also such rocks as the gneisses here described.

The composite gneisses of South Westland are coarse grained, foliated rocks in which quartz, biotite, plagioclase (acid oligoclase to medium andesine), and muscovite are the essential constituents. Either orthoclase or microcline may be present in small amounts in a few instances, while sillimanite is developed in some of the coarser-grained rocks, where the influence of pegmatitic solutions has been particularly potent. Apatite is constantly present, and may even rise to about 2% of the total composition of some specimens, while tourmaline, magnetite, and less commonly sphene or zircon are the usual accessories. Marked parallelism of the micas is a conspicuous feature of the gneisses of this group. Another highly characteristic textural feature is the development of myrmekitic intergrowths of plagioclase and quartz, while similar intergrowths of quartz with muscovite (Pl. 27, Fig. 5) and rarely biotite (Pl. 26, Fig. 4) are perfectly displayed in sections representing specimens collected from the immediate vicinity of pegmatite contacts. The effects of retrogressive metamorphism subsequent to the main crystallisation are seen in partial sericitisation of feldspar and chloritisation of biotite, accompanied by such cataclastic features as undulose extinction in quartz grains, partial granulation of quartz and feldspar, bending of cleavage-laminae in the micas, and development of microcline-structure in orthoclase.

No. 1278 (bushed knoll, one mile south of Mr J. Cron's homestead, near mouth of Haast River). Macroscopically this is a moderately coarse-grained gneiss with rather poorly developed banding and foliation, and having the general appearance of a granite-gneiss. In section, however, it is seen to consist of feldspar 40%, quartz 20%, biotite 20%, muscovite 20%, and occasional large irregular grains of apatite. The feldspar is entirely plagioclase, with the optical properties of acid andesine approximately $Ab_{67}An_{33}$, and frequently shows albite twinning. It occurs in large crystals from 0.5 mm. to 1 mm. in diameter, which in some parts of the section have been reduced by crushing to masses of angular grains of much smaller size. The grains of quartz are highly irregular, and vary from 0.1 mm. to 1 mm. in width, the usual mode of occurrence being as aggregates of small grains showing sutured or mosaic texture, which have evidently originated by crushing and recrystallisation of larger individuals. Strongly pleochroic deep reddish-brown to pale yellow biotite and colourless muscovite occur in xenoblastic flakes from 0.5 mm. to 1.5 mm. in length, often much twisted and frayed as a result of shearing (Pl. 26, Fig. 3). Incipient alteration of biotite to epidote, or to chlorite and included sphene, may occasionally be observed.

No. 1279, from the same locality, is a closely similar though somewhat coarser rock, in which quartz is more plentiful and muscovite much less abundant than in No. 1278. The feldspar is entirely plagioclase with the composition of medium andesine $Ab_{60}An_{40}$, and occurs in large partially sericitised grains which show only slight signs of crushing. The quartz, on the other hand, is in considerable-sized interstitial masses of angular or sutured grains, occupying the spaces between the feldspathic parts of the section. Stout prisms of apatite about 0.5 mm. long are abundant, while zircon and finely granular magnetite are less plentiful accessories.

No. 1280 (Big Bluff, Haast Valley) is macroscopically similar to the two preceding specimens, except that the micas show more pronounced parallelism and the foliation is consequently more conspicuous. The minerals present are quartz 20%, feldspar 35%, biotite 15%, muscovite 30%, and magnetite 0.5%, with plentiful apatite and tourmaline and rare zircon as accessory constituents. The quartz is in small, extremely irregular grains, which usually show undulose extinction, and are sometimes diablastically enclosed by porphyroblasts of feldspar. The latter mineral appears to be acid oligoclase, and occurs as xenoblastic crystals of small size, rarely showing albite twinning, and also as shapeless porphyroblasts about 2 mm. in diameter, which often enclose rounded quartz grains. In some of these masses quartz and feldspar are intergrown on a fine scale, and constitute a true myrmekitic intergrowth, throughout which the minute vermicular inclusions of quartz extinguish simultaneously. Large ragged porphyroblasts of deep reddish-brown biotite and small xenoblastic flakes of muscovite are plentiful. Both micas often show the effects of shearing, and the biotite is frequently slightly chloritised. The tourmaline is in relatively large idioblastic prisms, which may be blue, brown, or sometimes blue with a brown border. The apatite is faintly but very distinctly pleochroic, from bluish (X) to a very pale green tint (Z), the absorption being weak (X > Z).

No. 1281 (Big Bluff, Haast Valley) is of the same general type as the preceding specimen (No. 1280), but differs from the latter rock in the absence of porphyroblasts of plagioclase and biotite, and in the presence of orthoclase to the extent of about 5% of the total composition. This occurs as ragged interstitial masses from 0.2 mm. to 1 mm. in diameter, which usually enclose very numerous rounded grains of quartz and plagioclase, and which are conspicuous on account of their low refractive index and water-clear appearance. The plagioclase—medium oligoclase—is subordinate to quartz. It may be untwinned or sometimes twinned according to the albite law, and rarely is seen to form myrmekitic intergrowths with quartz. Though these intergrowths were sometimes observed at plagioclase-orthoclase junctions, while in one or two instances rounded inclusions of myrmekite are actually enclosed by orthoclase, the formation of myrmekite appears on the whole to be independent of proximity to orthoclase. The accessory minerals include abundant magnetite and minor epidote, apatite, sphene, and zircon.

The rocks from Big Bluff are in every way intermediate between the gneisses further west (Nos. 1278 and 1279), in which foliation is not pronounced and the feldspar is andesine, and the perfectly schistose, relatively fine-grained quartz-plagioclase-biotite-schists of Thomas Bluff (No. 1282) in which the feldspar is albite-oligoclase.

The development of thin bands of composite gneiss from biotite-hornfels adjacent to dykes of pegmatite 1 ft. to 5 ft. in width, may easily be observed at various points along the track on the southern bank of the Arawata River, between one mile and one and a-half miles west of the mouth of the Jackson. The following series of specimens from this locality exemplify successive stages in the development of gneiss from hornfels:—No. 1329, biotite-hornfels; No. 1330, fine-grained gneiss; No. 1331, coarse-grained gneiss; No. 1332, very coarse gneiss immediately adjacent to pegmatite margin.

No. 1329, which has already been described on p. 192, is a typical biotite-hornfels, consisting of a granoblastic mosaic of grains of quartz, biotite and albite (Ab_{98} to Ab_{95}) averaging 0.2 mm. in diameter, accompanied by a small quantity of muscovite in large porphyroblasts with sieve-structure.

No. 1330 differs from the adjacent hornfels mainly in the gneissic structure and considerably coarser grain-size, which is here approximately 0.5 mm. The constituents are quartz 30%, feldspar 40%, biotite 30%, muscovite 1%, and accessory apatite, sphene, magnetite, secondary epidote, and rarely zircon. The quartz occurs in small aggregates of sutured grains, the result of subsequent recrystallisation of larger grains under stress during retrogressive metamorphism. The feldspar is albite-oligoclase approximately $Ab_{90}An_{10}$, and is in the form of somewhat sericitised xenoblastic grains which quite often are twinned according to the albite law. The deep reddish-brown biotite in places appears to be undergoing replacement by muscovite along the cracks. Porphyroblastic muscovite is absent.

No. 1331 macroscopically is a typical coarse-grained gneiss rich in large crystals of micas, and containing light-coloured veinlets of quartz and feldspar about 3 mm. in width, which give the rock a foliated appearance and appear to be a direct product of igneous injection. The section represents one of the more micaceous bands, and consists of quartz 40%, feldspar 25%, muscovite 25%, biotite 10%, magnetite 1%, abundant apatite, and sphene, occasional zircon, and secondary epidote as less plentiful accessories. The grain-size is notably coarser than in the previous section, and varies from 0.3 mm. to 3 mm. The quartz constantly shows undulose extinction, and occurs either in large irregular grains about 1 mm. in width or else in broken-down aggregates of sutured granules. The large untwinned crystals of feldspar prove to be acid oligoclase, and are often considerably altered to sericite. Reddish-brown biotite forms large ragged flakes, which sometimes contain small zircons surrounded by dark pleochroic haloes, while stout xenoblastic grains of apatite are plentiful. In comparison with the previous two sections the most striking mineralogical feature is the presence of very plentiful fibrous muscovite in highly irregular masses and streaks, some of which are continuous across the full width of the section. In some instances this mineral appears to have effected partial or complete replacement of biotite with simultaneous formation of magnetite, sphene, and epidote in small quantities. In others it appears to have formed at the expense of the feldspar, while in other cases again it has simply crystallised as interstitial masses between the quartz aggregates.

No. 1332 represents one of the quartzo-feldspathic bands in a coarse gneiss immediately adjacent to the margin of a pegmatite dyke. The essential minerals are quartz 60%, feldspar 25%, muscovite 10%, and biotite 5%. The texture is exceedingly coarse, the average grain-size of the principal minerals being 3 mm. to 5 mm. The feldspar occurs in large, highly irregular masses, which penetrate interstitially between the quartzes, and is always considerably altered to sericite. The refractive index is distinctly lower than that for the ordinary ray in quartz, and traces of multiple twinning indicate that it is probably albite-oligoclase. The presence of orthoclase is improbable, since in the gneisses of this group, potash feldspar is almost invariably water-clear and free from sericitisation. The large ragged flakes of deep brown biotite have in many cases suffered partial replacement by delessite, through which wisps of muscovite, granular sphene, and magnetite are scattered in small amounts. The muscovite occurs in masses of small, irregular twisted flakes, with sparsely distributed inclusions of chlorite, magnetite, sphene, and rarely vermicular quartz. The accessories include several large grains of apatite and occasional small crystals of zircon. The quartz is particularly coarse-grained, and shows very clearly the effects of retrogressive metamorphism subsequent to the main crystallisation. The large crystals show marked undulose extinction, and are traversed by innumerable cracks, while in many instances they have undergone partial recrystallisation under shearing stress, so that clear areas of small interlocking sutured grains have been [illegible] either along the periphery of the parent crystal or in some cases enclosed deep within it. Absence of cracks in these secondary areas indicates that the recrystallisation occurred subsequently to the shattering and cracking of the large individuals. In a recent account of the phenomena of retrogressive metamorphism, Eleanor Knopf (1931) gives an instructive description of the textural criteria by which phyllonites (phyllite-mylonites) may be recognised, and makes the following statement, which is of interest in its bearing upon the origin of the textural peculiarities of the quartz grains in the section described above: "Particularly characteristic of phyllonites is the development of quartz lenses or nests of quartz grains that result from the breaking down of larger quartz individuals" (Knopf, 1931, p. 18). In specimen No. 1332 this breaking down process has not proceeded beyond the initial stages.

At the south-western end of the bridge which spans the gorge of Martyr Creek at its upper end, the metamorphic effects of pegmatite intrusions upon the surrounding biotite-hornfelses attain a maximum intensity, and bands of very coarse grey gneiss several feet in width here border the intrusive dykes. In the resultant rock the development of closely spaced, thin streaks, and discontinuous bands rich in biotite has given rise to a most pronounced gneissic structure, which is accentuated by marked parallelism of the mica flakes. The crystals of biotite increase in size and abundance as the pegmatite margin is approached, and the actual contact itself is marked by special abundance of both biotite and muscovite in flakes which sometimes attain from 1 cm. to 5 cm. in width. In the immediate vicinity of the pegmatite masses the gneiss contains well-defined veinlets and lenses of quartz and feldspar, which conform to the foliation and vary from 1 cm. to 5 cm. in thickness, while in several specimens lenticular masses of pure feldspar as much as 5 cm. thick in crystalline continuity throughout were noted. Quartz-feldspar bands of this type are obviously the product of injection of igneous material from the adjacent pegmatites.

The surrounding hornfels into which these gneisses imperceptibly pass is typified by Nos. 1200 and 1201 (north-east end, Martyr Bridge), which are relatively coarse-grained granoblastic rocks, the mineral composition of which is quartz 50%, acid oligoclase 25% to 30%, biotite (partly chloritised) 15% to 20%, coarsely porphyroblastic muscovite 2%, and accessory apatite, brown tourmaline, magnetite, and secondary sphene. The grains of the three principal constituents average 0.5 mm. in diameter.

No. 1337 is typical of a number of sections which were cut from specimens of coarse grey gneiss about 1 ft. to 2 ft. distant from pegmatite contacts. It differs from the surrounding hornfels mainly in the strongly gneissic structure and coarser grain, both of which are strikingly apparent in the hand-specimen, but the mineral composition proves to be surprisingly similar, being quartz 45%, acid oligoclase 30%, biotite 20% to 25%, muscovite 2%, with iron ore and abundant coarse apatite as accessories. As in the hornfels, both quartz and feldspar show undulose extinction. The plagioclase rather frequently is twinned after the albite law. The deep red-brown biotites are arranged parallel to the foliation, and sometimes contain marginal inclusions of sagenetic rutile.

No. 1338 (south-west end, Martyr Bridge) represents the very coarse mica-rich contact phase developed at the actual contact between pegmatite and gneiss. Two sections were cut and examined, the average mineral composition being quartz 20%, feldspar 15%, biotite 15%-20%, muscovite 40%, sillimanite 5%, apatite 2%, iron ore 1%. The texture is very coarse, the average grain-size of the four main constituents being 2 mm. to 3 mm. The bulk of the quartz occurs in irregular interlocking grains of large size, with marked undulose extinction and often containing lines of minute dark inclusions. It also very commonly takes the form of perfectly developed vermicular inclusions intergrown with plagioclase (myrmekite), muscovite (Pl. 27, Fig. 5), or even biotite (Pl. 26, Fig. 4). Such inclusions are often in optical continuity over areas 2 mm. or more in diameter, in which they need not necessarily be restricted to one particular enclosing crystal, nor even to crystals of one particular mineral. In several instances vermicular quartz of a myrmekitic intergrowth was observed to be optically continuous with that of an adjacent intergrowth of quartz and muscovite, while occasionally an individual vermicular body of quartz may even be enclosed partly in muscovite and partly in the adjoining plagioclase. The feldspar includes both orthoclase and acid oligoclase, the former predominating. The orthoclase is very coarsely crystalline, faintly dusted with kaolin, and sometimes shows patchy incipient development of microcline twinning, especially in strained and shattered crystals with strongly undulose extinction. Much of the orthoclase is traversed by irregular veinlets and patches of muscovite which has formed along the cracks (Pl. 27, Fig. 6), and in this way may often have replaced more than half of the original crystal. Oligoclase is in coarse clear crystals which nearly always contain abundant vermicular inclusions of intergrown quartz—a perfect example of myrmekitic intergrowth. Though the myrmekite may sometimes be adjacent to or even enclosed in crystals of potash feldspar, elsewhere it is in contact with crystals of quartz or mica, and its development thus appears to be entirely independent of the presence of orthoclase. The most abundant constituent of the rock is muscovite, which may occur as large ragged crystals some of which appear to have been formed at the expense of potash feldspar, and also as streaks and patches of fibrous muscovite which certainly replace orthoclase or microcline. Intergrowths of muscovite and quartz, throughout which the quartz inclusions are optically continuous, are exceedingly common. Sometimes the quartz is in the form of curving and twisted vermicular bodies of relatively large size (0.4 mm. × 0.1 mm.), comparable with those of the myrmekite described above. Elsewhere it takes the form of closely packed rectilinear inclusions (1 mm. × 0.01 mm.) arranged parallel to the cleavage of the intergrown muscovite. Fine-grained regular intergrowths of this last type not uncommonly fringe large crystals of muscovite devoid of inclusions, especially where the latter lie adjacent to partially replaced crystals of orthoclase or microcline. The biotite is very strongly pleochroic (X = very pale brownish yellow, Y = Z = very deep reddish-brown), and in rare instances appears to have undergone partial replacement by muscovite. Intergrowths of biotite and fairly coarse vermicular quartz are not common, but occasionally constitute a conspicuous irregular fringe around biotite crystals without inclusions (Pl. 26, Fig. 4). The biotite of the central crystal is always in optical continuity with that of the bordering intergrowth, while the quartz inclusions of the latter are elongated parallel to the cleavage of the enclosing biotite. Sillimanite is somewhat sporadically distributed through the rock, but is often very plentiful in the coarse mica-rich areas. It is in idioblastic slender prisms about 0.5 mm. × 0.05 mm., which are usually grouped in uniformly parallel or sometimes felted aggregates in close association with crystals of biotite or muscovite. Less commonly smaller groups of parallel prisms lie along the margins of the quartz or feldspar crystals, or, more rarely still, scattered crystals of sillimanite may actually be enclosed within grains of these minerals. Several clear instances were noted in which masses of prismatic sillimanite have partially replaced both biotite and muscovite, small ragged remnants of which still persist throughout the replacing felt of sillimanite prisms, much as described by Tattam (1929, pp. 19, 24) in gneisses from North-east Victoria. In other cases the crystals of mica fray out terminally into a fringe of parallel prisms of sillimanite, a phenomenon which seems to be not uncommon in composite gneisses of this type (e.g., see Sugi, 1930, p. 78; Adams and Barlow, 1910, p. 133). Very coarse grains of apatite, which may reach 3 mm. in diameter, are fairly plentiful. Epidote occurs as very rare yellowish grains derived from the biotite, while fairly coarse magnetite has sometimes been formed as a secondary product during replacement of biotite by sillimanite. As compared with the adjacent grey gneiss (e.g., No. 1337) the main features of the contact-gneiss described above are very coarse grain, abundance of muscovite, presence of sillimanite and orthoclase, and development of intergrowths of quartz with plagioclase, muscovite, or biotite on a very perfect scale.

Nos. 1335, 1202, and 1203, from the southern end of Martyr Bridge, are also typical examples of the coarse contact phase of the gneiss of this locality.

No. 1335 represents a band richer in quartz and feldspar than No. 1338, and consists of quartz 25%, feldspar 40%, biotite 15%, muscovite 20%, sillimanite 1%, with accessory quantities of magnetite, coarse apatite, and sphene. Orthoclase is absent, all the feldspar being acid oligoclase (about $Ab_{85}An_{15}$), which often shows albite twinning. Sillimanite is not so well developed as in the previous section. It normally occurs as swarms of acicular prisms enclosed in muscovite or as fringes of parallel needles fraying out from the borders of some of the biotite crystals, though in rare instances it may be enclosed by quartz or plagioclase. Myrmekite and quartz-muscovite intergrowths are very perfectly and plentifully developed, while rather indefinite intergrowths of quartz and biotite are much less frequent. In other respects the section closely resembles the preceding one (No. 1338).

A description of Nos. 1202 and 1203 has already been given (Turner, 1930a, pp. 175-176). They are essentially similar to Nos. 1335 and 1338 described above, but differ in several important respects. Intergrowths are practically absent, muscovite is not nearly so plentiful as in the previous specimens, while sillimanite is more abundant. Orthoclase appears to be absent, but plagioclase (oligoclase-andesine, $Ab_{70}An_{30}$) is abundant in slightly altered, often well-twinned crystals.

The hornfelsic paragneisses, which outcrop in the gorge of the minor tributary which drains into Martyr Creek about one mile and a-half above its junction with the Cascade River, have also been invaded by numerous small dykes of pegmatite and veins of nearly pure quartz. These intrusions have never affected the invaded rocks sufficiently to develop definite bands of composite gneiss, but their metamorphic effects, though confined to very narrow marginal zones, are nevertheless distinct and somewhat comparable with the much more complete alteration displayed in the other areas considered. The contact between hornfelsic gneiss and a tourmaline-pegmatite is shown in section No. 1222 (Turner, 1930a, pp. 177, 181-182).

With reference to the origin of the composite gneisses the following features are significant, and may be discussed at this stage:—

(a.) The field occurrence. The composite gneisses usually occur as marginal bands along the contacts between hornfelses or hornfelsic paragneisses, and the swarm of pegmatite veins which invade them. In the northern part of the map, however, extensive masses of composite gneiss veined with pegmatite occupy considerable areas near the sea coast, and merge gradually eastward into the quartz-biotite-plagioclase schists of the Haast Valley, where pegmatites are absent. The field relations alone therefore clearly indicate that the recrystallisation of the composite gneisses into their present condition was due to the metamorphic influence of the invading pegmatites upon the invaded hornfelses, paragneisses, and schists. The increase in temperature resulting from such intrusion cannot have been great, for the invading bodies themselves were of only small magnitude; but percolating magmatic fluids thoroughly permeating rocks which had already attained a high temperature, as a result of recent uprise of a subjacent batholith, would certainly be potent agents capable of bringing about complete recrystallisation and introducing new material of magmatic origin. This general permeation appears to have been of much greater importance than actual lit-par-lit injection, which is by no means common, and is restricted to the immediate vicinity of some of the larger dykes.

The importance of large-scale impregnation and " soaking " of the surrounding rocks during batholithic invasion is well known, and has recently been emphasised by Fenner (1914, pp. 697-699; 718-721), who draws attention to the conclusions deduced in this connection by Lacroix and Michel-Levy from observation of contact phenomena in the Pyrenees. In his recent account of the injection rocks of the Tsukuba district of Japan, Sugi (1930, pp. 77, 101-102) also stresses the importance of igneous impregnation in the genesis of this type of rock.

In the Haast-Cascade area the magmatic impregnation responsible for the formation of the composite gneisses was connected with the pegmatitic phase of igneous intrusion, not with the main uprise of granite magma which evidently preceded it and was responsible for the initial hornfelsing.

(b.) Gneissic texture. The composite gneisses all exhibit well-developed gneissic texture, dependent upon the arrangement of crystals of biotite, and less commonly muscovite, parallel to the pegmatite-gneiss contacts. The dykes of pegmatite themselves display a marked tendency to parallelism in any given locality, so that the whole mass might often be described as a lit-par-lit injection gneiss on a very coarse scale. It follows, therefore, that the intrusion of the pegmatite and the attendant metamorphic alteration of the adjacent rocks must have taken place under powerful directed stress.

(c.) Presence of orthoclase or microcline. Except in rare instances potash feldspar is absent from the unmodified hornfelses, schists, and paragneisses of the district. On the other hand, microcline or orthoclase, though by no means universal, may often be noteworthy constituents of the composite gneisses, especially in the coarser phases adjoining pegmatite contacts. It appears highly probable, therefore, that the potash feldspar of these rocks has been introduced by potash-bearing fluids from the invading pegmatites, especially in view of the fact that microcline or orthoclase are usually plentiful in these latter rocks (Turner, 1930a, pp. 181-182).

(d.) Typically muscovite, is much more prominent in the composite gneisses than in the parent rocks, and there is further a marked tendency for this mineral to be especially abundant, along with equally plentiful biotite, in the highly micaceous contact phase which usually is developed along the pegmatite margins. While much of the coarse muscovite appears to be primary, in other cases aggregates of fibrous muscovite seem to have partially or entirely replaced crystals of other minerals, notably orthoclase, plagioclase, and biotite. Much of the muscovite is thus probably of magmatic origin, and, like the potash feldspar, has formed under the influence of potassic pegmatitic fluids.

It has already been pointed out that some of the invaded hornfelses (e.g., Nos. 1218 and 1342) contain muscovite in two totally distinct habits—small clear-cut flakes scattered through the granoblastic mosaic, and large ragged porphyroblasts sieved through and through with quartz inclusions. It is suggested, therefore, that the porphyroblastic muscovite of the hornfelses like that of the composite gneisses owes its potash content to percolating magmatic fluids, a suggestion which is strongly supported by the almost universal presence of associated microcline in small amounts in hornfelses of this type.

(e.) Apatite and tourmaline are almost universally distributed in accessory amounts through all the metamorphic rocks of Southern Westland, and are doubtless due largely to emanations from subjacent masses of granite. Very coarse apatite of undoubted pegmatitic origin is especially plentiful in many of the composite gneisses, while in one instance (No. 1222) coarse idioblastic tourmaline, has been developed in a similar manner at the contact between hornfelsic paragneiss and a tourmaline-pegmatite.

(f.) The composition of the plagioclase. In the composite gneisses the feldspar is mainly plagioclase, ranging from acid or medium oligoclase in the majority of cases to acid andesine or even andesine of medium composition. The chemical composition of the plagioclase is thus found to correspond moderately closely with that of the parent rocks. It is well established that the feldspars of the plagioclase series are very sensitive to changes in conditions of metamorphism, and that while albite is the stable member under low-grade metamorphic conditions, anorthite enters increasingly into the composition as the grade of metamorphism becomes higher. It therefore appears that the conditions of temperature and pressure which obtained during the period of pegmatite injection were not greatly different from those which prevailed during the preceding hornfelsing phase of metamorphism, since the composition of the plagioclase was much the same in each case.

In most cases the plagioclase of the pegmatites corresponds closely in composition with that of the adjacent gneiss, the limits of variation in the former case being $Ab_{90}An_{10}$ and $Ab_{67}An_{33}$. It is therefore possible that in certain instances the plagioclase of the invaded hornfels may have been modified to conform with that of the intrusive pegmatite, by local reaction with pegmatitic fluids during crystallisation of the resultant composite gneiss. Such reaction is difficult to demonstrate, since the plagioclase of both the hornfelses and the pegmatites must have been of approximately the same composition in the first place. It has already been shown, however, that potash feldspar has been introduced into many of the composite gneisses, while the coarsest gneisses from Martyr Bridge contain large masses of plagioclase sometimes 5 cm. or more in diameter, which could have crystallised only from pegmatitic solutions, or as a result of metamorphic diffusion.

(g.) Development of sillimanite. The sillimanite of the composite gneisses is strictly confined to the highly altered mica-rich gneiss immediately adjacent to pegmatite contacts, and it may therefore reasonably be inferred that one of the conditions essential for its development was thorough permeation of the gneiss by pegmatitic fluids. A further significant feature is that the sillimanite is very frequently intimately associated with biotite or muscovite, the former of which it appears actually to replace in certain instances. It may here be noted that Marshall (1907, p. 500) and Speight (1910, p. 261) have described a gneiss from Dusky Sound, West Southland, in which needles of sillimanite frequently crowd the plates of muscovite much as in the Cascade Valley gneisses. Association of sillimanite with biotite in highly metamorphosed rocks in the vicinity of granitic or sometimes basic plutonic masses appears to be a frequent occurrence, and has been described in greater or less detail by many writers on metamorphic petrology (e.g., Barrow, 1893, p. 338, Pl. XVI, Fig. 2; Watt, 1914, p. 279; Greenly, 1919, p. 136; Read, 1923, pp. 152, 153, 154; Ghosh, 1927, p. 305, Pl. VII, Fig. 11; Tattam, 1929, pp. 17, 19; Sugi, 1930, p. 78). Muscovite and sillimanite often show a similar relation (e.g., Gardiner, 1890, p. 576; Adams and Barlow, 1910, p. 133; Thomas, 1925, p. 53; Sugi, 1930, p. 78), while Bailey (1925, p. 52) and Thomas (1925, p. 54), in discussing the metamorphic effects of the Ross of Mull granite, stress the importance of reaction between muscovite and quartz, as giving rise to the sillimanite which is so characteristic of the inner zone of the contact aureole.

In his recent account of the metamorphic rocks of North-east Victoria, Tattam (1929, pp. 17, 19) describes replacement of biotite by sillimanite in " schistose hornfelses " and in xenoliths enclosed in granite gneiss. With reference to this reaction he later makes the following statement (Tattam, 1929, p. 45) : " This phenomenon occurs in schistose sedimentary material, either in direct contact with or close to magmatic solutions. Biotite gradually disappears, while sillimanite of approximately the same volume takes its place. The process is not one of simple decomposition, since biotite could not supply sufficient alumina to form the sillimanite, and there is no concomitant precipitation of iron oxides or hypersthene. Biotite probably goes into solution, and it may lose some alumina which augments the main supply used in building up sillimanite. Most of the alumina required for that purpose must come from some other source, possibly from muscovite, and if this assumption is correct alkali must leave the system. If the phenomenon has been rightly interpreted, a general reshuffling of material must have occurred, and the changes are brought about not by simple chemical decomposition, but by differences in dynamic physical equilibrium in different parts of the rock, the chemical constituents forming minerals which are stable under the various conditions."

In the rocks described by Tattam and the sillimanite-gneisses of Martyr Bridge it therefore seems that sillimanite has been developed at the expense of biotite, and that magmatic fluids have played an essential part in bringing about this reaction. In the

Martyr Bridge rock, moreover, there is evidence of similar replacement of muscovite by sillimanite. In this latter connection it is perhaps possible that some of the potash feldspar present in these gneisses may have originated along with sillimanite by the breaking down of muscovite in the presence of siliceous solutions, as pictured by Bailey (1925, p. 52) in the case of the aureole surrounding the Ross of Mull granite. However, the exact nature of the mechanism by which the micas have given rise to sillimanite in the gneisses of Martyr Bridge still remains obscure.

In discussing the action of granitic liquid upon xenoliths of argillaceous sediment, N. L. Bowen (1922, pp. 561, 562) has stated that an intermediate product of the reaction might be sillimanite, which, however, would later be made over into mica if complete reaction between liquid and xenolith were allowed to take place. In the present instance it is difficult to explain the presence of sillimanite on Bowen's hypothesis, for the petrographic relationship of sillimanite to mica in these rocks is such that the former mineral must have crystallised subsequently to the development of coarse micas already alluded to. In any case the presence of sillimanite in the composite gneisses indicates conclusively that the pegmatites were injected under conditions of very intense metamorphism.

(h.) Presence of " graphic " intergrowths. One of the most characteristic features of the coarser-grained composite gneisses adjacent to pegmatite contacts is the presence of " graphic " intergrowths of plagioclase and quartz, muscovite and quartz, or, less commonly, biotite and quartz. The most widespread of these are typical myrmekitic intergrowths of plagioclase and highly vermicular quartz.

According to Holmes (1920, p. 164) the term myrmekite was introduced in 1899 by Sederholm to include intergrowths of " plagioclase and vermicular quartz, generally replacing potash feldspars, formed during the later or paulopost stages of consolidation or during a subsequent period of plutonic activity." Later writers (e.g., Becke, 1908; Tilley, 1921a, pp. 87, 88; Sugi, 1930, p. 39; Read, 1931, p. 149) have stressed the fact that myrmekite usually develops where crystals of plagioclase are in direct contact with orthoclase or microcline, and it is thus generally held to be a product of replacement of potash feldspar by acid plagioclase. According to this view (Sederholm, 1916; Tilley, 1921a, p. 88) the formation of myrmekite in granitic rocks is a special phase of albitisation.

Sugi (1930, pp. 40, 66, 67) nevertheless describes several cases where the myrmekite cannot have originated in this way, and shows that in these particular instances the intergrowth has probably been produced by partial replacement of plagioclase by quartz.

It has already been shown that in the composite gneisses of the Haast-Cascade area, development of myrmekite is independent of the presence or proximity of potash feldspar, for intergrowths of this type are commonly found in rocks from which orthoclase and microcline are both completely absent. The most perfect development is attained in rocks which also contain plentiful quartz-muscovite or quartz-biotite intergrowths, and it therefore appears that all three have a common origin. Moreover, the prevalence of these phenomena in the most highly altered gneisses immediately adjoining the dykes of pegmatite clearly indicates that they have originated by the action of pegmatitic fluids upon the invaded rocks.

A brief survey of some of the more important literature dealing with contact metamorphism reveals the fact that micrographic intergrowths of all kinds appear to be highly characteristic of rocks formed near igneous contacts, as a result of incomplete reaction between liquid magma or magmatic fluids and invaded rocks or xenoliths. These include not only myrmekitic intergrowths of plagioclase and quartz (e.g., Watt, 1914, pp. 280, 283; Collins, 1917, pp. 59-62), but also such associations as biotite-quartz, biotite-feldspar, biotite-cordierite (Watt, 1914, pp. 282, 284), quartz-orthoclase, quartz-tourmaline, quartz-hornblende, hypersthene-plagioclase-magnetite (Read, 1923a, pp. 463, 466, 472, 478), corundum-biotite, and corundum-sillimanite (Ghosh, 1927, p. 305). In the cases cited above the micrographic textures are seen sometimes in the altered xenoliths or invaded rock, and sometimes in the contaminated igneous rock itself. Fenner (1926, pp. 737, 753), in discussing the origin of graphic intergrowths of quartz and feldspar, has recently drawn attention to the conclusion of Coleman (1907, p. 774) and Collins (1917, p. 62) that such textures may be considered as diagnostic criteria of rocks which have originated by reaction between magma and country rock.

In view of the above facts it is concluded that the intergrowths described in the present paper originated during the later stages of the pegmatitic phase of metamorphism, by partial replacement by quartz of original plagioclase, muscovite, or biotite, large crystals of which now act as hosts to the graphic or vermicular quartz inclusions. This type of origin has already been demonstrated by Sugi (1930, pp. 40, 66, 67) for some myrmekitic intergrowths, and by other writers (e.g., Schaller, 1925, p. 20) for graphically intergrown quartz and orthoclase.

(i.) Retrogressive metamorphic effects. The mechanical effects of retrogressive metamorphism are very pronounced, and include shattering and recrystallisation of quartz and feldspar, twisting of micas and bending of feldspar twin lamellae, and development of undulose extinction in various minerals. Orthoclase has frequently inverted to microcline under the influence of stress, while much of the albite twinning seen in the plagioclase is probably to be attributed to the same cause (compare Alling, 1921, pp. 209, 210). The purely chemical effects, on the other hand, are not as conspicuous as in the finer-grained hornfelses.

(10.) *Origin of Quartzo-Feldspathic Schists, Gneisses, etc.:* Although the quartzo-feldspathic group of schists, gneisses, etc., includes rocks of widely different metamorphic facies, their mineral composition indicates certain persistent chemical features which stamp them as having originated in all cases from a common parent rock. Quartz and sodic plagioclase always predominate, while potash feldspar is entirely lacking except in a few cases where there is reason to believe that it has been introduced by pegmatitic fluids. Chlorite, white mica, and epidote are usually moderately plentiful in rocks of low metamorphic grade, while red-brown biotite, minor muscovite, and small amounts of epidote or clinozoisite characterise the rocks which have suffered more intense metamorphism. The rocks thus fall into the Group of Plagioclase-gneisses in Grubenmann's chemical classification (Grubenmann, 1910, p. 179).

The mineralogical characteristics outlined above suggest derivation from sediments consisting originally of detrital quartz, plagioclase, and fairly plentiful ferromagnesian silicates. Sediments of this nature might have originated in the first place as quartz sands admixed with basic tuffaceous material, or, more likely, as " ferromagnesian sands " (Van Hise, 1904, p. 877) formed by rapid disintegration of igneous rocks of basic and intermediate composition. It is significant that upon cementation such sands would give rise to greywacke, a rock which is universally abundant in the older rock systems of New Zealand.

MICACEOUS SCHISTS.

The micaceous members of the metamorphic series include those rocks in which the micas biotite and muscovite, together with chlorites, predominate over combined quartz and feldspar. With increase in the latter constituents they grade into various members of the quartzo-feldspathic group. The micaceous schists do not constitute a distinct stratigraphic unit, but for the most part occur as bands of minor importance intercalated among the quartzo-feldspathic schists, gneisses, etc.

(1.) *Muscovite-chlorite-quartz-albite-schists:* Of the numerous specimens which consist mainly of the quartz-albite-muscovite-chlorite association, which is so typical of the lower grades of metamorphism in this area, only one, No. 1302, contains sufficient muscovite and chlorite to warrant classification among the micaceous schists. This specimen was collected by Mr C. R. Bentham from near the Main Divide at the head of the Wilkin Valley, about 20 or 25 miles southwest of Haast Pass.

Macroscopically the rock is a lustrous pale greenish grey schist with perfect foliation, obviously rich in mica. The constituent minerals include muscovite 40%, chlorite 25%, quartz 20%, feldspar 10%, epidote 5%, and accessory amounts of sphene, magnetite, and apatite. Ragged flakes of muscovite and chlorite about 0.5 mm. in length are arranged parallel to the foliation, giving a thoroughly lepidoblastic texture to the rock. The muscovite has an unusually small optic axial angle, which, judging from the interference figure, cannot be much above 10°. The chlorite is delessite similar to that recorded in the quartz-albite-chlorite-schists, with distinct pleochroism from pale greenish yellow (X) to deep green (Y and Z). The grains of quartz are highly irregular, frequently sutured, and vary from 0.05 mm. to 0.5 mm. in diameter. Those of feldspar are of similar size, water-clear, and untwinned, and have the optical properties of almost pure albite. Epidote is scattered plentifully throughout the whole section in pale yellow strongly birefringent prisms and granules, about 0.1 mm. in length. Sphene in colourless rounded granules is an abundant accessory, while there are also a number of large irregular grains of apatite and magnetite.

The essential difference between specimen No. 1302 and the quartz-albite-chlorite schists is that muscovite is much more plentiful than in the latter rocks, while quartz and albite are correspondingly less abundant. Whereas the presence of much muscovite indicates a noteworthy amount of argillaceous matter in the parent sediment, the persistence of the chlorite-albite-epidote association also points to the presence of basic igneous material in some quantity. The initial sediment thus appears to have been a somewhat argillaceous band in the series of sands and silts of greywacke composition, of which the schists, gneisses, and hornfelses of the quartzo-feldspathic group are the highly metamorphosed equivalents.

(2.) *Foliated Muscovite-biotite-quartz-schists:* The dominant minerals in these rocks are muscovite and biotite, the former in small irregular flakes and the latter as larger, sometimes porphyroblastic crystals, which may be sieved with inclusions of quartz. Quartz usually constitutes from 20% to 30% of the rock, but feldspar seems to be absent. Crystals of both micas show a considerable degree of parallelism, thus imparting to the rock a distinct and characteristic foliation.

Foliated muscovite-biotite-quartz-schists are represented by only two specimens, Nos. 1209 and 1210, which were collected from the south-western part of the map, and have already been described in a previous paper (Turner, 1930a, pp. 177, 178).

(3.) *Hornfelsic Biotite-muscovite-schists:* So far the hornfelsic mica-schists are known only as rather rare boulders in the gravels of Laschelles Creek. They are fine-grained, brownish, imperfectly foliated rocks of almost hornfelsic aspect, usually mottled with large knots or single porphyroblasts of white mica. Biotite and muscovite are the dominant constituents, and are usually accompanied by quartz and feldspar (sodic plagioclase or microcline), which typically rank as essential components. The commonest accessories are tourmaline, magnetite, and apatite, while in one specimen (No. 1463) the tourmaline is present in such large quantities that the rock may be classified as a tourmaline-mica-schist. In another specimen (No. 1339) porphyroblastic chlorite accompanies the two micas, but is in quite subordinate proportions. The four examples described below are representative varieties of the hornfelsic mica-schists.

No. 1339 is a dark brown fine-grained rock mottled with numerous irregular patches of muscovite from 10 mm. to 20 mm. in length. The foliation is only poorly developed. The constituent minerals are biotite 40%, muscovite 25%, quartz 20%, feldspar 15%, chlorite 0.5%, and accessory tourmaline, magnetite, apatite, and sphene. The texture is distinctly porphyroblastic, with numerous large muscovites and much less plentiful smaller porphyroblasts of chlorite set in a groundmass of biotite, quartz, feldspar, and fine muscovite. The feldspar is untwinned, and appears to be medium oligoclase, about $Ab_{80}An_{20}$ to $Ab_{76}An_{24}$. The biotite is intensely pleochroic, from pale yellow to deep sepia brown, and occurs in small ragged flakes showing some degree of parallelism. Muscovite occurs both as small flakes throughout the groundmass and as large highly-irregular porphyroblasts and knots of coarse crystals, sieved through with numerous rounded inclusions of quartz and rarer grains of biotite or magnetite. The chlorite is a pale green variety identical with that which has already been described in connection with specimen S.W. 30 (p. 199), but lacks the characteristic polysynthetic twinning displayed in the latter section. It takes the form of small clear-cut porphyroblasts about 1 mm. in length, enclosing abundant rounded inclusions of quartz and ragged ones of iron ore. Small idioblastic prisms of brown tourmaline and grains of magnetite are plentiful, and are accompanied by occasional grains of apatite and sphene.

No. 1340 is macroscopically very similar to No. 1339, but contains neither chlorite nor feldspar, and lacks the development of coarse muscovite which is so characteristic of the previous specimen.

No. 1463 is a fine-grained brown hornfelsic schist spotted with coarse knots of white mica, and closely resembling No. 1339 in hand-specimen, except that the foliation is even less distinct than in the latter specimen. The rock is remarkable for the great abundance of tourmaline, the mineral composition being biotite 30% to 40%, muscovite 40%, tourmaline 20% to 25%, feldspar 1%, quartz 2%, and accessory iron ore and apatite. The biotite is mostly in unoriented deep red-brown semi-porphyroblastic crystals (about 0.5 mm. × 0.2 mm.), but may be considerably coarser in the immediate vicinity of the muscovite knots, which are often fringed by discontinuous borders consisting almost entirely of these larger biotites. Tiny flakes of muscovite 0.1 mm. in diameter are very plentiful, while the same mineral builds coarsely crystalline porphyroblastic knots enclosing numerous granules of brown tourmaline. The tourmaline never takes the form of large crystals, but occurs as innumerable small, stout idioblastic prisms (0.05 mm. to 0.4 mm. in length) or rounded grains scattered throughout the whole section. It is the usual brown type with strong pleochroism from very pale yellow (X) to golden brown, sometimes faintly tinged with blue (Z). This curious rock may be classed as a tourmaline-mica-schist.

No. 1344 is a greyish-brown schist with very plentiful rounded porphyroblasts of silvery muscovite 3 mm. to 5 mm. in diameter uniformly distributed across the broken surface, giving the hand-specimen a most distinctive appearance. The section consists mainly of biotite, muscovite, and microcline in approximately equal proportions, together with quartz and albite-oligoclase, which together make up 10% to 15% of the rock. The accessory constituents are magnetite, apatite, sphene, and secondary epidote. Deep reddish-brown biotite occurs as rather small unoriented flakes without inclusions. The muscovite, on the other hand, builds large ragged porphyroblasts flattened parallel to the foliation planes, and sieved with plentiful rounded grains of quartz and occasional small crystals of biotite, though microcline is never enclosed in this manner. Microcline, with the usual " grid-iron " twinning, is developed as clear crystals about 0.5 mm. to 0.8 mm. in diameter, which always enclose small granules of quartz, magnetite, and muscovite. The plagioclase lacks such inclusions, and is often much altered to sericite. The rock is unique among the specimens collected from the Haast-Cascade area on account of its high microcline content, and may be classed as a microcline-mica-schist.

The predominance of biotite and fine-grained muscovite in the hornfelsic mica-schists points to derivation from initial pelitic sediments. Recrystallisation of this sediment into its present condition appears to have been controlled mainly by high temperature, probably aided by considerable hydrostatic pressure, but accompanied by only minor directed stress, this latter factor being responsible for the present imperfect foliation of the rocks under consideration.

During recrystallisation the original sediment appears to have been modified in composition by magmatic fluids, to the action of which the formation of porphyroblastic muscovite, microcline, and tourmaline is attributable. Development of porphyroblasts of muscovite under the influence of magmatic fluids has been noted by Tattam (1929, p. 17) in the case of certain of the " schistose hornfelses " of Victoria, and a similar origin has already been suggested, earlier in this paper, for the coarse muscovite of the composite gneisses and quartzo-feldspathic hornfelses. It is probable, too, that the abundant microcline of specimen No. 1344 has been similarly introduced from magmatic sources, since potash feldspar is only rarely a constituent of the other metamorphic rocks of this area, and is present only in rocks which have undergone thorough permeation by igneous emanations. Introduction of tourmaline may have preceded the development of coarse muscovite, since in specimen No. 1463 (where tourmaline is very plentiful) small idioblastic crystals are frequently enclosed in the large knots of muscovite.

The field relations of the hornfelsic mica-schists are unknown, and it is therefore impossible to state definitely whether their recrystallisation took place during the hornfelsing stage of the metamorphic cycle or the subsequent period of pegmatitic injection. In the writer's opinion, however, the petrographic evidence lends support to the first of these alternatives.

ALBITE-EPIDOTE-SCHISTS.

The albite-epidote-schists are represented by only two specimens, Nos. 1284 and 1310, in both of which albite is the dominant constituent, and is accompanied by very plentiful epidote, which makes up 20% or 25% of the total composition of the rock, the third essential component being quartz. While these schists resemble the rocks of the quartzo-feldspathic group, in that quartz and feldspar together constitute 60% to 80% of the rock, they differ in the great abundance of epidote and unimportant development or even absence of chlorite, muscovite, and biotite.

No. 1284 (boulder, Mule Valley, three miles north of Haast Pass) is a pale green fine-grained homogeneous schist with perfectly developed foliation. The mineral composition is albite 35% to 40%, epidote 25%, quartz 20%, actinolite 5% to 10%, chlorite 7%, calcite 1%, and accessory pale greenish mica, magnetite, and sphene. The average grain-size of the essential constituents is about 0.1 mm., though in the more feldspathic areas the grains of albite and quartz are a little larger than this. The feldspar is almost pure albite ($Ab_{98}An_2$) in water-clear untwinned interlocking granules. The epidote is aggregated into clusters of small xenoblastic grains with strong pleochroism in greenish and yellowish tints. The birefringence as determined by comparison with that of quartz is about 0.04, so that the mineral is an iron-rich epidote containing about 28% of the $HCa_2Fe_3Si_3O_{13}$ molecule (Winchell, 1927, p. 355). The chlorite is a pale greenish pennine with very low birefringence, and shows anomalous yellowish brown interference tints. Very slender prisms and needles of pale green actinolite about 0.3 mm. to 0.5 mm. in length are plentiful and freely penetrate the other minerals present, especially some of the larger crystals of albite. There are a number of scattered grains of calcite, which often enwrap rounded grains of quartz. The only mica present is a distinctly pleochroic colourless to pale green variety which may be phlogopite, and which occurs in rather rare flakes of small size. A similar pale mica has recently been mentioned by Dr. F. C. Phillips (1930, p. 244) in his description of the Green Beds of the Scottish Dalradian, where it is sometimes an important constituent of schists of the chlorite zone.

No. 1310 was collected from a boulder in the bed of the Jackson River, a quarter of a mile above its junction with the Arawata. It is a highly fissile white to pale greenish schist dotted plentifully with tiny bright grains of magnetite (tested with a magnet). The rock consists of albite 60%, epidote 20%, quartz 15% to 20%, chlorite 3%, biotite 1%, and magnetite 1%. These minerals build up a mosaic of small grains (0.2 mm. in average dimension), among which somewhat larger albites and well-shaped crystals of magnetite occasionally tend to porphyroblastic development. The albite is water-clear, usually untwinned, but sometimes shows either simple or multiple twinning. The optical properties indicate that the anorthite content does not exceed 5%. Subidioblastic stout prisms of yellow epidote are plentiful, the high birefringence (0.045) showing it to be an iron-rich variety containing about 30% of $HCa_2Fe_3Si_3O_{13}$. Chlorite, though not abundant, is conspicuous on account of its unusually strong absorption. It is apparently a ferruginous delessite, uniaxial, negative, poorly birefringent, and strongly pleochroic, from light brownish yellow (X) to deep green (Y and Z). Biotite is less plentiful than chlorite (with which it is often interlaminated), and shows striking pleochroism from pale yellowish brown to very deep green—almost black. There is also a very small quantity of colourless to pale green mica similar to that of the preceding section. It is confined entirely to very narrow rims which partially or completely surround the porphyroblasts of magnetite. This curious feature recalls somewhat similar structures described by Brammall

(1921, pp. 213, 214, 222) in certain phyllites from Bolivia. In these latter rocks porphyroblasts of ilmenite have been built up during reconstitution of the chloritic constituents of the rock, and later have become ensheathed in narrow selvages of transversely disposed fibres and prisms of muscovite and quartz. It is suggested (Brammall, 1921, p. 222) that as a result of tension caused by shrinkage of the groundmass during the reconstitution process, the porphyroblasts of ilmenite became detached from the surrounding matrix, and the spaces so formed were later filled in by the quartz and muscovite which now constitute the surrounding selvages. In the present specimen (No. 1310) there appears to be but little evidence either in support of or against such a mode of origin. It is certainly difficult to imagine how such a mineral as phlogopite or muscovite could arise by any process involving reaction between magnetite and surrounding albite, while the sharply cut boundaries of the magnetite crystals themselves point to absence of any such reaction. It should be noted, however, that whereas in the Bolivian rocks the transverse disposition of the prisms of quartz and muscovite is taken by Brammall as being indicative of secondary origin, in the present specimen the selvages do not show this feature, but are built up of tiny flakes of mica arranged parallel to the margins of the central magnetite grains.

From a genetic point of view the oustanding petrographic features of the albite-epidote-schists are unusual abundance of albite and epidote combined with almost complete absence of micas. The association of albite and epidote conclusively points to plagioclase of intermediate composition as the main source of both these minerals, though the presence of small amounts of chlorite indicates that the original rock may have contained minor quantities of pyroxene or amphibole, the lime contact of which may now be represented by a small proportion of the epidote. The highly ferruginous nature of the latter mineral also suggests the probable presence of femic minerals in the parent rock. It therefore seems probable that the initial rock of which the albite-epidote-schists are the metamorphic equivalent consisted largely of intermediate plagioclase, accompanied by a noteworthy amount of quartz and small quantities of iron oxides and ferromagnesian silicates. Dacites, dacite-tuffs, and highly feldspathic sands are rocks whose mineral composition might agree with that outlined above. The relatively large proportion of quartz, however, appears to preclude derivation from dacitic rocks. On the other hand, origin by metamorphism of a highly feldspathic sand is strongly supported by the field association with an extensive series of metamorphic rocks which are themselves the completely recrystallised and reconstituted equivalents of grits and silts of greywacke composition containing plentiful plagioclase. Scarcity of micas in the albite-epidote-schists points to absence of argillaceous material from this initial sediment.

FERRUGINOUS SCHISTS.

The ferruginous schists are represented by a single specimen of garnetiferous quartz-magnetite-haematite-schist obtained from a boulder in the bed of the Jackson River, 10 miles above its junction with the Arawata. The bulk of the rock is a finely laminated schist, consisting of very thin regular layers alternately quartzose and rich in iron ore. Careful testing with a magnet shows that the latter is largely magnetite in the form of minute shining grains, though the presence of haematite in some layers is shown by the red colour of the powdered mineral. There are also irregular porphyroblasts of magnetite as much as 2 mm. in length, elongated parallel to the schistosity. There is a single band, from 2 cm. to 3 cm. in thickness, which is most conspicuous on account of an abundant development of exceedingly coarse porphyroblastic masses of magnetite from 10 mm. to 15 mm. in diameter. These are set in a light-coloured pinkish matrix throughout which aggregates of finely prismatic green amphibole are interwoven.

Section No. 1317 (Pl. 28, Fig. 12) was cut from the fine-grained portion of the specimen, and consists of quartz 60%, iron ores 35%, amphibole 4%, and garnet 1%. The quartz forms a mosaic of interlocking equidimensional grains (0.1 mm. to 0.3 mm. in diameter), often with well-developed sutured texture. Iron ores, with a bright steely glitter in reflected light, are very plentiful, and vary in form from individual grains 0.1 mm. in diameter to elongated granular aggregates about 1.5 mm. × 0.4 mm. disposed parallel to the foliation. Though magnetite is plentiful, much of the iron ore is haematite, the grains of which appear blood-red at the margins when viewed under high power magnification. In a duplicate section, however, haematite is completely lacking, and magnetite is correspondingly more abundant. Slender prisms of pale bluish-green to colourless actinolite are present throughout, but tend to be concentrated in the magnetite-rich layers. The only remaining constituent is pale yellowish garnet, which occurs in minute grains and idioblastic crystals 0.01 mm. to 0.02 mm. in diameter, which are especially numerous in the iron-rich bands.

Section No. 1316 represents the coarse layer alluded to above. The composition is magnetite 25%, garnet 50%, amphibole 20%, and quartz 5%, though some parts of this band contain a considerably higher percentage of quartz than appears in the section. The large porphyroblasts of magnetite are set in an almost opaque matrix of very finely granular, yellowish brown garnet throughout which are interspersed clear patches and streaks of prismatic pale bluish green amphibole. The quartz is present as irregular grains of small size. In view of Tilley's (1926; 1926a) observations upon the significance of the presence of manganese in garnet, a chemical qualitative test for this metal was carried out on garnet separated from this rock. Abundant manganese was indicated.

The parent rock from which this curious schist originated can only have been a quartz-magnetite sandstone, containing also a minor proportion of aluminous ferromagnesian silicates now represented by garnet and actinolite. From the complete absence of albite, epidote, and micas in the schist it may reasonably be inferred that clastic plagioclase and argillaceous matter were totally lacking in this parent sediment. The rock thus differs widely from the other types so far described in this paper, and is therefore placed alone in a separate class as a ferruginous schist.

GREEN SCHISTS.

The green schists are well foliated rocks which are conspicuous in the hand-specimen by reason of their distinctive light to dark green colour. Microscopically they are characterised by abundant development of chlorite, epidote, or amphibole, associated with less though still important amounts of sodic plagioclase and quartz. Chlorite and epidote are the dominant femic minerals of the lower metamorphic grades, while deep blue-green amphibole and less commonly biotite are distinctive of rocks which have suffered more intense metamorphism. Magnetite and sphene are constantly present as accessory constituents.

(1.) *Chlorite-epidote-albite-schists:* The chlorite-epidote-albite-schists are represented by one specimen collected from a boulder in the Haast Valley, and by a number of boulders and pebbles in the bed of the Jackson River. These latter have probably been brought down from the belt of low-grade metamorphic rocks (quartz-albite-chlorite-schists) which is drained by the upper part of the Jackson River, east of the peridotite belt.

The members of this group vary considerably in composition, but usually contain both chlorite (pennine) and epidote in abundance, though in extreme cases either mineral may be almost absent. These two characteristic minerals are invariably accompanied by plentiful, often porphyroblastic albite and minor quartz, while grains of both magnetite and sphene are usually numerous. In some specimens small quantities of calcite suggest transition towards the chlorite-calcite-epidote-schists described in the next section.

No. 1314 (boulders, upper ford, Jackson River) consists of epidote 45%, chlorite 25%, muscovite 10% to 15%, quartz 10%, albite 5%, sphene 1%, magnetite 1%, and accessory apatite. Though calcite was not seen in the section, its presence as a minor constituent was determined by testing the hand-specimen with dilute acid. Highly birefringent, pleochroic ferruginous epidote is unusually plentiful, and takes the form of xenoblastic grains and idioblastic prisms averaging 0.2 mm., but sometimes reaching as much as 1 mm. in length. The chlorite is deep green to yellowish green pennine, in coarse irregular pleochroic flakes which give a positive biaxial interference figure, though the optic axial angle is apparently small. Ragged wisps of muscovite sometimes interlaminated with chlorite are conspicuous, while rounded grains and wedge-shaped crystals of sphene 0.1 mm. to 0.2 mm. in diameter are relatively abundant. The latter are easily distinguished from epidote by their higher refringence and birefringence, positive sign, and much smaller optic axial angle. Quartz occurs as clear patches about 1 mm. across, composed of interlocking sutured grains of small size, as well as in isolated grains scattered through the chlorite-epidote-muscovite matrix. Undulose extinction is often pronounced.

No. 1319 (boulder, lower ford, Jackson River) is a deep green fine-grained rock containing abundant small flakes of chlorite clearly visible in the hand-specimen. The rock may be regarded as an extreme member of the chlorite-epidote-albite-schists in which epidote is nearly absent, the constituent minerals being chlorite 40% to 50%, feldspar 30% to 40%, quartz 10%, calcite 3%, sphene 3%, iron ore 2%, amphibole 1% to 2%, and accessory apatite and epidote. As is usual in this group of schists, the chlorite is a strongly pleochroic pennine ($X = Y =$ deep green; $Z =$ pale yellowish) with very low birefringence and strong dispersion, which combine to give yellowish brown and purplish interference tints when the section is viewed between crossed nicols. It is positive and definitely biaxial, but the optic axial angle is small. The feldspar is almost pure albite in clear, usually untwinned grains 0.4 mm. to 0.8 mm. in diameter, which may sometimes contain sparsely scattered inclusions of epidote, chlorite, amphibole, fine magnetite, or rarely sphene. It is accompanied by smaller irregular grains of quartz with slightly undulose extinction. The calcite takes the form of highly xenoblastic crystals of relatively large size, usually without inclusions, but sometimes enclosing swarms of amphibole needles. Small colourless grains of sphene are very abundant, and yield good positive biaxial interference figures showing strong dispersion of the optic axes. It is intimately associated with irregular granules of iron ore—presumably ilmenite—with which it often appears to build composite aggregates. These are almost invariably enclosed within flakes of chlorite, which are often crowded with numerous inclusions of this nature (Pl. 28, Fig. 10), suggesting origin from original titaniferous augite. Isolated needles and tufts of pale green to colourless actinolite are constantly present in small amount and often penetrate the other constituents.

Nos. 1347 and 1348 are specimens collected from a single boulder of coarse-grained green chlorite-schist in the bed of Laschelles Creek. In section it is an unusually coarsely crystalline somewhat feldspathic schist of variable composition, the chief constituents (an average of four sections) being chlorite 15% to 20%, epidote 15%, feldspar 40% to 50%, muscovite 10% to 20%, sphene 2% to 5%, and iron ore 2%, together with actinolite, tourmaline, rutile, and apatite as plentiful accessories. The feldspar is almost pure albite in the form of large untwinned xenoblastic crystals, in which shearing subsequent to crystallisation has often produced marked undulose extinction, or even partial recrystallisation of the albite into a mosaic of small interlocking grains. Inclusions of epidote and iron ore are often extremely plentiful, and are sometimes accompanied by locally abundant grains of sphene, needles of rutile or actinolite, or prisms of blue tourmaline. Inclusions of this type frequently show no sign of regular arrangement, but in some parts of the section they are elongated parallel to one another and disposed in regular, usually curved strings which show marked parallelism over limited areas of the section. Rounded grains of quartz (0.05 mm.) and small flakes of chlorite are also enclosed occasionally in the large albite crystals. The chlorite is a strongly pleochroic delessite (X = yellowish; Z = deep green), giving purplish red anomalous interference tints between crossed nicols. It occurs in relatively coarse flakes about 1 mm. in diameter, which typically are interlaminated with ragged flakes of muscovite of similar size. In contrast with the albite these chlorite-muscovite patches are usually almost devoid of inclusions, while the masses of pure chlorite contain relatively few included grains of epidote. Highly ferruginous epidote with a birefringence of 0.038 to 0.040 is consistently plentiful in all the sections examined, and takes the form of small granules and prisms about 0.2 mm. long, enclosed in the more coarsely crystalline minerals, especially in albite. It is sometimes accompanied by scattered small needles of pale green actinolite. Magnetite occurs as plentiful xenoblastic grains enclosed in the large feldspars, as well as in the form of irregularly distributed porphyroblastic octahedra 1 mm. to 5 mm. in diameter. Coarse grains of apatite are present in accessory amount. An unusual feature shown by this rock is local abundance of sphene, tourmaline, and rutile either separately or sometimes associated with one another. The rutile takes the form of very slender yellow needles, always enclosed in albite. In some crystals of the latter they are extremely numerous, while in adjacent grains of feldspar or chlorite they are entirely lacking. The distribution of sphene and tourmaline is also far from uniform. These two minerals are concentrated, either independently or in close mutual association, in irregular sinuous streaks not more than 0.5 mm. in width, which may extend for between 5 mm. and 10 mm. across the section, and which appear to represent lines along which pneumatolytic vapours have penetrated the schist. These streaks are continuous through feldspar and chlorite alike, and their course seems to bear no relation to the present texture. Furthermore, in cases where streaks of this type cross feldspars which have suffered partial recrystallisation under shearing stress, their trend is in no way influenced by zones of secondary granulation so produced. It appears, therefore, that the tourmaline-rich and sphene-rich streaks originated at an early stage of metamorphism before the present texture had been developed. The tourmaline itself is strongly pleochroic, from very pale yellowish violet to deep greenish blue, and occurs in small, idioblastic, often parallel prisms, which are practically confined to the streaks described above. Sphene, on the other hand, though especially concentrated along bands of this type, is also abundant as inclusions in chlorite and albite throughout all the sections examined. The exact source of this interesting rock is unknown. The metamorphic grade is much lower than that of the hornfelses and associated rocks of the area drained by Laschelles Creek, and it is highly probable, therefore, that the boulder from which the specimens were collected was not derived from the hornfels area of Laschelles Creek, but was washed from the late Pliocene conglomerates which underlie the moraines of the Cascade Plateau.

(2.) *Chlorite-calcite-albite-epidote-schists:* The rocks grouped under this heading are represented by specimens collected from boulders in the bed of the Jackson River and its eastern tributaries. As in the case of the chlorite-epidote-albite-schists the grade of metamorphism is low, and it is therefore surmised that all these rocks have been derived from minor bands of green schists intercalated among the low-grade quartzo-feldspathic schists along the range east of the Jackson River, beyond the eastern limit of the zone of quartz-plagioclase-biotite-schists.

The essential feature of the schists of this type is the presence of plentiful calcite accompanying the usual chlorite-epidote-albite association so characteristic of green schists of low metamorphic grade. Albite is more plentiful and epidote distinctly less abundant than in the chlorite-epidote-albite-schists just described. The percentage of epidote is usually about 5% to 15%, but in certain instances (e.g., No. 1320) this mineral is almost totally absent. Chlorite is always plentiful, and may be either positive pennine or negative delessite, while sphene and magnetite are characteristic accessory constituents. Two typical specimens are described below:—

No. 1313 (plentiful boulders, Turnley Creek, Jackson Valley). Macroscopically the rock is a light green silky chloritic schist with numerous small porphyroblastic knots of calcite and feldspar about 1 mm. in diameter, which impart to the hand-specimen a distinctive granular appearance. As seen in section the constituents are chlorite 25%, calcite 25%, albite 30%, epidote 15%, quartz 5%, and accessory sphene and apatite. The feldspar is almost pure albite, with an extinction angle of 22° measured from X to the 001 cleavage in sections perpendicular to the acute bisectrix Z. It occurs in large untwinned or in rare cases simply twinned porphyroblasts with more or less rounded outlines, which usually enclose numerous elongated grains of epidote accompanied by minor sphene and chlorite. In many instances these inclusions are arranged in regular parallel strings cutting through the porphyroblasts without any relation to the direction of elongation of the latter. The texture thus approaches the perfect helicitic texture displayed by certain other members of the Green Schist group (e.g., No. 1291) described later in this paper, and is closely similar to that of a chlorite-epidote-albite-schist from the start area described and figured by Dr Tilley (Tilley, 1923, p. 84; Pl. X, Fig. 1). Large irregular porphyroblasts of calcite sometimes as much as 3 mm. in diameter are very plentiful (Pl. 28, Fig. 9). This mineral is almost universally twinned, and usually encloses scattered inclusions of epidote, chlorite, and albite. These large crystals of calcite and albite are set in an enwrapping matrix which consists of fairly coarsely crystalline, pale green faintly pleochroic pennine, and small granules of colourless epidote, albite, and quartz.

No. 1318 (numerous boulders, upper ford, Jackson River). Macroscopically the rock is an even-grained deep green schist, in which dark chloritic layers 3 mm. in thickness alternate regularly with thin white laminae 0.5 mm. to 1 mm. thick, in which calcite is a prominent constituent. The whole rock is sparsely dotted with octahedra of magnetite from 1 mm. to 8 mm. in diameter. A section cut parallel to the foliation from one of the white bands consists of calcite 40%, albite 30%, quartz 15%, chlorite 10%, epidote 5%, magnetite 1%, and accessory sphene. Porphyroblastic texture is not developed, and the albite, the composition of which approximates to $Ab_{93}An_7$, is usually devoid of inclusions. Calcite is so plentiful in some parts of the section that it forms a coarsely crystalline continuous matrix, in which scattered rounded crystals of albite (about 0.3 mm.) and clear patches of granular quartz and albite are enclosed. Deep green, almost isotropic, chlorite and strongly pleochroic yellow epidote tend to be associated with one another, and are often accompanied by small granules of pale sphene.

(3.) *Biotite-calcite-albite-epidote-schist:* This rock is known from a single specimen, No. 1326, collected from a boulder near the mouth of the Jackson River. It is a coarse-grained dark green schist, in which biotite, chlorite, and porphyroblastic white feldspar and calcite are all plainly visible to the unaided eye. The constituent minerals are biotite 25%, calcite 20%, feldspar 25%, epidote 15%, chlorite 10%, quartz 5%, actinolite 1%, and accessory apatite and sphene. The feldspar is albite (Ab_{90} to Ab_{95}), and occurs as rounded crystals from 2 mm. to 5 mm. in diameter, which rarely show traces of albite twinning. They enclose numerous unoriented grains of yellowish epidote, parallel acicular prisms of actinolite, flakes of chlorite, and rarely grains of quartz or calcite. Since biotite is never thus included by the large albites, it may be inferred that the latter ceased to grow prior to the period when the biotite commenced to form. Large highly irregular crystals of calcite, often enclosing scattered granules of epidote, are numerous, and nearly always show lamellar twinning. The biotite is in coarse flakes with strong pleochroism from light yellowish to deep golden brown, and lacks the characteristic red-brown tint so frequently observed in that of the quartzo-feldspathic schists and gneisses. The chlorite is pennine, strongly pleochroic, from light yellow (Z) to deep green (X and Y), uniaxial, optically positive, and poorly birefringent (about 0.004). Epidote is plentiful throughout the whole section. The iron content of this mineral varies from moderately high to low, often within the limits of a single crystal. There is also a small proportion of actinolite in small acicular prisms with faint pleochroism from light yellow (X) to pale blue-green (Z). Quartz is a minor constituent only, and appears as small clear grains without inclusions. Coarse grains of apatite (0.2 mm. to 0.5 mm.) are fairly plentiful, while sphene is a minor accessory.

The rock is somewhat similar to the porphyroblastic chlorite-calcite-albite-epidote-schist No. 1313, from which it differs mainly in the presence of abundant biotite and in the more calcic composition of the plagioclase, pointing to a distinctly higher grade of metamorphism. Further, it is evident from the presence of biotite in No. 1326 that this rock and No. 1313 are chemically by no means identical, for the low-grade equivalent of the former rock must have contained muscovite to supply the necessary potash for the later development of biotite. In this respect chemical affinities are shown with muscovite-bearing chlorite-epidote-albite-schists such as No. 1314, which differ, however, in containing no calcite.

(4.) *Amphibole-plagioclase-epidote-schists:* Amphibole schists of this group are by no means common, and have so far been collected from stream boulders only. Very numerous boulders of this nature were observed in the beds of Douglas Creek, Haast Valley, and the small creek which drains into the Haast from the west about one mile below the Burke confluence. It is therefore probable that the rocks occur *in situ* in association with normal quartz-plagioclase-biotite-schists along the range in the vicinity of Mount Defiant and Pivot Peak, where both these streams have their headwaters. Similar boulders were obtained from the Jackson River and its tributary, Turnley Creek, and have doubtless been derived from a source among the quartz-plagioclase-biotite-schists which flank the Jackson Valley on the south-east.

The amphibole-plagioclase-epidote-schists are compact, highly fissile rocks, which are easily distinguished in hand-specimen by their deep green colour. Blue-green amphibole is always an essential constituent, and is constantly accompanied by abundant sodic plagioclase and a less but still important amount of epidote. Slight variations in chemical composition and metamorphic grade have produced corresponding variations in the mineral assemblages developed in different specimens. Thus biotite and chlorite may sometimes be sufficiently plentiful to rank as essentials. Quartz is always present as a minor constituent, while calcite, magnetite, and sphene are common accessories.

No. 1287 (boulders, Douglas Creek, Haast Valley) is typical of the highest grade of metamorphism attained by the amphibole-schists of the Haast-Cascade area. The constituents are amphibole 50%, feldspar 20%, epidote 7% to 10%, biotite and chlorite 10%, iron ore 5% to 10%, quartz 5%, and accessory apatite. The amphibole occurs in very slender prismatic crystals 0.5 mm. to 1 mm. in length (Pl. 28, Fig. 11), which show marked parallelism and impart a coarsely nematoblastic texture to the rock. The feldspar is acid oligoclase, $Ab_{88}An_{12}$, and takes the form of rarely twinned interstitial grains about 0.2 mm. in diameter scattered among the prisms of amphibole. It usually shows pronounced undulose extinction. Small grains of epidote and black iron ore (about 0.05 mm.) are plentiful, and frequently are enclosed within the larger crystals of plagioclase. The epidote is pale yellow or colourless, faintly pleochroic, and has only moderate birefringence (about 0.016). This latter property indicates a clinozoisite content of about 90%, so that the composition lies on the boundary between clinozoisite and pistacite as defined by Winchell (1927, pp. 354 to 356). Deep yellowish brown, strongly pleochroic biotite occurs in highly irregular flakes 0.3 mm. in diameter, which are often interwoven with masses of amphibole prisms, while associated with the biotite is a minor amount of pale green pennine. Clear grains of quartz are sparsely distributed throughout the section, and there are also several large xenoblastic crystals of apatite. The amphibole is a strikingly pleochroic variety with strong absorption, according to the following scheme:—

X = light yellowish.
Y = deep olive green.
Z = deep greenish blue.
$X < Y < Z$, Y and Z being nearly equal.

The extinction angle measured from Z to the vertical axis in the clinopinacoidal section is about 15°, the optical sign is negative, and the birefringence is approximately 0.020. Amphibole, with a deep blue or greenish blue tint for light vibrating parallel to Z, appears to be very characteristic of amphibole-schists and amphibolites of high metamorphic grade (e.g., compare Collins, 1917, p. 32; Stillwell, 1918, p. 38; Hunter, 1925, p. 33; Phillips, 1930, p. 246). The authorities quoted above all refer to the mineral simply as hornblende, though Stillwell (1918, p. 38) suggests that the blue colour is due to admixture of the glaucophane molecule. The optical properties of the Westland amphibole are identical with those of the mineral which J. P. Smith (1907, p. 190) described from the glaucophane-schists of California under the name " carinthine." In his recent chemical survey of the hornblende group, Kunitz (1930) groups the amphiboles into seven distinct isomorphous series, the first four of which (anthophyllite-cummingtonite, tremolite-actinolite, glaucophane-riebeckite, and glaucophane-actinolite) are characteristically developed in metamorphic rocks. The remaining three groups (green hornblendes, syntagmatitic hornblendes, and alkali-iron-amphiboles) are confined to igneous rocks. In view of its distinctive blue Z tint, relatively low extinction angle, and acicular habit it seems probable that the amphibole now under consideration would belong to the glaucophane-actinolite series of Kunitz (1930, p. 202) rather than to his group of igneous green hornblendes. Furthermore, Blasdale's analysis of the Californian " carinthine " (Smith, 1907, p. 191) clearly indicates that this mineral belongs to the actinolite end of the actinolite-glaucophane series. The deep blue tint referred to cannot be taken as an indication that the glaucophane molecule enters extensively into the composition of this amphibole, for Kunitz himself observes (Kunitz, 1930, p. 201) that blue-green tints are by no means confined to highly sodic amphiboles, and are due not to the presence of unusually high soda, but rather to iron in the ferric condition. Murgoci (1906, pp. 371, 372) has also observed that whereas the soda content may control the shade of colour exhibited by amphiboles of this type, the depth of the tint is determined by the Fe_2O_3 content. The green schists of the Haast and Jackson Valleys contain amphiboles which show every gradation from almost colourless or pale green actinolite (e.g., No. 1319), through varieties with slightly deeper absorption and a pale bluish green Z tint (e.g., No. 1326), to the striking blue-green amphibole just described. Furthermore, the series outlined above corresponds closely with regularly increasing metamorphic grade, as will be shown in a later section.

No. 1312 (boulders, Turnley Creek, Jackson Valley) is of the same general type as the previous section, but differs in that it contains more quartz and feldspar, less amphibolé, and very little biotite. The composition is amphibole 30%, feldspar 30%, epidote 20%, quartz 15%, and chlorite 3%, with magnetite, biotite, sphene, and apatite in accessory quantities. The texture is nematoblastic, due to development of parallel prisms of amphibole (1 mm. × 0.1 mm.). The latter is almost identical with the blue-green amphibole of specimen No. 1287, but the absorption is slightly less intense, and the extinction angle (Z to c) appears to be about 18°. The feldspar is albite-oligoclase approximating to $Ab_{90}An_{10}$. Biotite is almost absent, being limited to two or three small flakes with deep brown absorption, but strongly pleochroic delessitic chlorite ($X =$ pale greenish yellow, $Z =$ deep green) is somewhat more plentiful. In the section magnetite is represented only by rather rare grains of moderate size, but in the hand-specimen it is conspicuously developed as idioblastic octahedra several millimetres in diameter.

No. 1291 (boulder, creek one mile below Burke confluence, Haast Valley). Macroscopically the rock is a deep green schist in which conspicuous flakes of dark biotite and white porphyroblasts of feldspar are plainly visible to the unaided eye. The component minerals are amphibole 10%, albite-oligoclase 35%, epidote 15%, biotite 15%, chlorite 10%, quartz 10%, and calcite 5%. The texture is porphyroblastic due to the development of large crystals of untwinned albite-oligoclase averaging 2 mm. × 1 mm. These helicitically enclose strings of elongated epidote granules (sometimes accompanied by needles of amphibole) which show perfect parallelism in any particular porphyroblast, and often extend beyond the limits of the feldspar crystal into the adjacent chlorite-amphibole matrix or into a second feldspar individual. The orientation of these lines of inclusions is unrelated to the direction of elongation of the enclosing feldspar, and though their trend is more or less constant over restricted areas it is by no means uniform throughout the section as a whole. Where they approach the opposite sides of a porphyroblast the strings of epidote are usually distinctly bent in opposite directions. A further conspicuous feature is a uniform tendency for the lines of included material to be concentrated towards the centre of the crystal with respect to a direction at right angles to their trend. The biotite is in ragged crystals about 0.5 mm. to 1 mm. in width with intense pleochroism from light yellowish to very deep greenish brown. Deep green nearly isotropic chlorite is also fairly plentiful, and in some places appears to be undergoing conversion into biotite. In other parts of the section swarms of slender prisms of blue-green amphibole identical with that of section No. 1287 have developed in parallel position through the chlorite, and seem to have been derived from it. Idioblastic prisms and rounded grains of poorly ferriferous epidote are very numerous, both as inclusions in the feldspars, and associated abundantly with the other femic constituents. There are several rather large twinned xenoblastic grains of calcite containing sparsely distributed inclusions of amphibole, magnetite, and epidote. Clear grains of sphene, sometimes enclosed in the albite porphyroblasts, are moderately plentiful, while less common accessories are magnetite and apatite. The striking helicitic structure shown by the large feldspars deserves some further comment. It is rather imperfectly approached in the chlorite-calcite-albite-epidote-schist No. 1313, and also in certain of the chlorite-albite-epidote-schists described by Dr. Tilley (1923, p. 84, Pl. 10, Fig. 1) from the Start area of Devon. Bailey (1923), in an account of the albite-schists of the south-east highlands of Scotland, has fully discussed structures exactly comparable with that shown by the present rock. He concludes that strings of epidote, oriented parallel to the schistosity of an early stage of metamorphism, have later become enclosed in growing porphyroblasts of albite, and that the latter have subsequently been subjected to mechanical rotation while still in the " living " state, as a result of shearing at a late stage (Bailey, 1923, p. 328). The twisting of the strings of epidote where they emerge from the enclosing porphyroblast has thus the same significance as the spiral structure of " snowball " garnets, in contrast with " rodded " structures which may result when porphyroblastic albite or garnet are subjected to shearing after they have ceased to grow. The helicitic texture of the rock from the Haast Valley may thus reasonably be taken to indicate that the process of metamorphism in this area has not been simple, but has involved at least three successive stages, in which formation of strings of epidote, growth of porphyroblastic feldspars, and finally mechanical rotation of the latter have respectively taken place.

S.W. 19 (Auckland University College collection) is a dark green schist collected from a boulder near the mouth of the Jackson River. It consists of amphibole 10% to 15%, albite-oligoclase 25%, epidote 35%, chlorite 20%, quartz 2% to 5%, biotite 1%, sphene 1%, and magnetite 1%. In section the rock has a most distinctive appearance, due to development of conspicuous large crystals of zoned epidote (1 mm. × 0.5 mm.), in addition to porphyroblastic feldspar and magnetite. Typically each epidote crystal contains a sharply defined core of yellow, highly ferruginous epidote, with a birefringence of 0.040 to 0.045, pointing to a composition of about 30% $HCa_2Fe_3Si_3O_{13}$ and a ferric oxide content of about 15% (Winchell, 1927, p. 355). These cores are often simply twinned and nearly always show idioblastic outlines, whereas the surrounding outer zone is universally xenoblastic in outline and is never twinned. The outer zone consists of clear colourless or pale yellow clinozoisite with a very wide optic axial angle and a birefringence not greater than 0.010, so that the mineral contains about 7% of the $HCa_2Fe_3Si_3O_{13}$ molecule, corresponding to a ferric oxide content of 3.3%. In addition to these compound crystals there are abundant small granules of yellow ferriferous epidote 0.1 mm. in width, and rare small porphyroblasts of clinozoisite without zoned structure. The amphibole occurs in sheaves of acicular prisms about 0.5 mm. in length. The pleochroic scheme is much the same as for the blue-green amphibole of the previous sections, but the absorption is less intense and the extinction angle is about 20°. The chlorite is a delessitic type, and occasionally shows transition into greenish brown biotite. Rounded grains of pale yellow sphene are very plentiful, usually in close association with the femic minerals.

(5.) *Origin of the Green Schists:* The less metamorphosed members of the green schist group of South Westland are closely similar to, though not identical with, the chlorite-schists of Central Otago, which occur as beds and lenses of usually minor extent, intercalated among the quartz-muscovite-schists which constitute the Maniototo Series (Park, 1906, p. 15; 1908, p. 25; 1909, p. 56).

According to Professor Park, the chlorite-schists of Central Otago originated by metamorphism of basic volcanic rocks. Finlayson (1908, pp. 75, 76) concluded from petrographical examination and chemical analyses that the chlorite-schists of Gibbston and the Dunstan Range are " altered flows or sheets of basic igneous rocks, contemporaneous with the associated mica-schists of sedimentary origin." More recently Professor Benson (1928, p. 57) has pointed out that while some of the chlorite-schists are sharply bounded bands which may represent lava-flows, others merge into the adjacent mica-schists, and have probably been derived from beds of basic tuff.

Petrographically the green schists of Otago and South Westland closely resemble those of well-known areas such as Anglesey, the Start area of Devon, the Scottish Highlands, and the Alps of Switzerland, where origin from basic tuffs or effusive rocks has been clearly demonstrated by detailed chemical and petrographic investigations.

If a close comparison is made with the rocks of the Start area it is clear that the green schists of the Haast and Jackson Valleys approach most closely those rocks which are grouped by Tilley (1923, p. 188) as " schists of composite origin." According to this writer (Tilley, 1923, pp. 188, 189) these composite schists are probably the metamorphosed equivalents of basic tuffs, and are distinguished from the essentially igneous green schists of the district by their variable composition and the presence of muscovite and quartz, which mark a transition towards the associated quartz-mica-schists of sedimentary origin. The green schists of Westland and Otago often contain either muscovite or biotite, the latter being developed only where the grade of metamorphism is relatively high, while granular quartz is always present to the extent of 5% or 10%.

The Westland schists also show a close resemblance to isogradic melanocratic members of the green bed group of the Scottish Dalradian. Dr. F. C. Phillips (1930, p. 240) concludes from recent investigation of these beds that though " they are readily seen, at least in the lower grades, to be of sedimentary origin, yet they possess distinctive chemical characteristics most readily explained by fairly direct derivation from basic igneous rocks, and deposition without much admixed material."

The present writer therefore suggests that the green schists of the Haast and Jackson Valleys have originated by metamorphism of tuffs of basic composition. A possibility that must not be overlooked, however, is that they may represent beds of sandstone or grit derived directly from the rapid disintegration of basic igneous rocks much as suggested by Dr. Phillips in the case of the Scottish green beds.

"RIEBECKITE"-SCHIST.

Schists carrying a considerable amount of deep blue amphibole close to riebeckite are represented by numerous large boulders in the bed of Douglas Creek, about five miles below the Clarke Hut, Haast Valley. These masses cannot have travelled any great distance, and have doubtless been derived from beds of schist associated with the green amphibole-schists and quartz-plagioclase-biotite-schists of Douglas Creek.

No. 1285 is a typical specimen. Macroscopically it is a blue, highly fissile, finely laminated schist, composed of thin layers alternately rich in light-coloured and femic constituents. Numerous small grains of pyrite are clearly visible in the hand-specimen. The composition (average of three thin sections) is albite 50%, quartz 20%, blue amphibole 10%, biotite 10%, epidote 5%, secondary muscovite 5%, and accessory calcite, apatite, magnetite, and pyrite. The albite, which approximates in composition to $Ab_{94}An_6$, occurs in small grains from 0.1 mm. to 0.2 mm., accompanied by occasional larger crystals, some of which reach 1 mm. in diameter. In some parts of the sections it has suffered partial replacement by innumerable tiny flakes of white mica, but in other areas the albite is water-clear and unaltered. Sericitisation of the albite is especially marked in parts of the sections where biotite is plentiful, and has sometimes resulted in almost complete replacement of the feldspar by dense finely felted masses of white mica. The biotite is pleochroic from pale green to dull greenish brown, and occurs either in irregular patches from 0.3 mm. to 2 mm. in diameter, or as plentiful tiny flakes scattered through the albite. Some layers of the rock consist almost entirely of coarse biotite and sericitised feldspar. The grains of quartz are always of small size, and occasionally may be diablastically enclosed by some of the larger albites. Subidioblastic small prisms of green highly ferriferous epidote occur abundantly throughout the section, frequently in close association with the amphibole. The latter mineral occurs in small slender prisms 0.2 mm. in length, often aggregated together in tufts. It is strongly pleochroic, according to the following scheme:—

X = deep indigo blue.
Y = deep lavender blue.
Z = pale greenish yellow.

The absorption is $X > Y > Z$, X and Y being strong and nearly equal, while Z is weak. The elongation is negative, the maximum extinction angle (X to c) in vertical sections being 12°. The optic axial angle is fairly small, the optic sign is negative, and the plane of the optic axes is parallel to the clinopinacoid, as in most amphiboles. The birefringence is approximately 0.015 as determined with a quartz wedge in clinopinacoid sections, but sections parallel to the orthopinacoid show very weak double refraction. There is strong dispersion of the bisectrices which renders exact determination of extinction angles a difficult matter. Though it is obvious that the mineral must belong to Kunitz's riebeckite-glaucophane series (Kunitz, 1930, pp. 196-200), which includes glaucophane, crossite, riebeckite, and crocidolite, the optical properties described above nevertheless do not correspond exactly with those of any recognised member of the amphibole group. It resembles glaucophane only in its blue colour, while it differs markedly from crossite in pleochroism, elongation, and orientation of the optic axial plane. It resembles riebeckite in the characteristic negative elongation, the position of the optic axial plane, the strong dispersion and the deep blue absorption tint for light vibrating parallel to X. The mineral nevertheless differs distinctly from riebeckite in its higher birefringence, larger extinction angle, and weaker absorption, as well as in the details of the pleochroic scheme. It is somewhat difficult to compare the amphibole under consideration with crocidolite, since the properties of the latter mineral are rather obscure, but it certainly lacks the typical fibrous habit of crocidolite. According to Murgoci (1906, pp. 369-370) the pleochroism and absorption of crocidolite resemble those of riebeckite, the optical character is positive, and the extinction angle (X to c) = 10° to 21°. Iddings (1906, p. 344) and Dana (1922, p. 493) both stress the fact that the extinction angle is high (18° to 20°), and Dana quotes the birefringence as 0.025, the optic sign being positive. Winchell (1927, p. 208), however, regards crocidolite merely as a fibrous variety of riebeckite, while a recent analysis of South African crocidolite made by Kunitz (1930, p. 198) shows that the composition is very close to that of riebeckite, but grades slightly towards that of crossite. It seems from the above that the amphibole under consideration definitely differs from crocidolite in having lower birefringence, small extinction angle, and negative optical sign, as well as in habit and pleochroism. Phemister (1926, pp. 32-35) has recently given a detailed account of a blue amphibole which occurs in alkali-syenites of the Loch Ailsh district of Scotland, and whose properties are almost identical with the blue amphibole from the Haast Valley. The pleochroic scheme (X = Prussian blue, Y = violet, Z = straw yellow) corresponds well with that quoted above for the amphibole of section No. 1285, but the absorption is quoted as $X < Y < Z$—the exact reverse of the present case. From the very nature of the tints quoted it would seem, however, that this is probably a misprint for $X > Y > Z$. Further, the elongation of Phemister's amphibole is given as negative (the extinction angle X to c being 1.5° to 14°), and, judging from the pleochroism displayed by other amphiboles, it is highly unlikely that this mineral would show minimum absorption for light vibrating parallel to the length of the crystal. Phemister (1926, p. 34) classes his amphibole as a member of the riebeckite-katophorite series close to riebeckite. The present writer, following Kunitz's classification, prefers to regard the amphibole of the Haast Valley schist as a member of the riebeckite-glaucophane series intermediate between riebeckite and crossite. It will be sufficient to refer to it in this paper as "riebeckite."

In his recent paper on the hornblende group, Kunitz (1930) includes the minerals of the riebeckite-glaucophane series among the amphiboles, which characteristically crystallise in metamorphic rocks. While glaucophane, crossite, and crocidolite are all typical metamorphic minerals, the end member riebeckite usually occurs in igneous rocks. Murgoci (1905, p. 143) quotes instances where Lacroix and others have described as riebeckite fibrous blue amphiboles from crystalline schists, but nevertheless suggests that these should probably be referred to crocidolite and states that in general riebeckite is not found in genuine schists. It is therefore of interest to note that the " riebeckite " of the Haast Valley schist is undoubtedly a product of metamorphism, and is paragenetically associated with albite, quartz, biotite, and epidote—a typical metamorphic assemblage*.

The development of " riebeckite," instead of the greenish blue amphibole of the normal amphibole-schists, requires explanation, and may be due to some peculiarity in chemical or mineralogical composition of the rock in question, or to some special conditions of metamorphism. Apart from the presence of " riebeckite " itself, and the fact that the feldspar is more sodic than that of the associated rocks, there is nothing to suggest that specimen No. 1285 is especially rich in either soda or iron in comparison with the associated green amphibole-schists, so that the actual chemical composition of the rock does not appear to have been the controlling factor. In the green amphibole-schists the characteristic blue-green amphibole seems to have been generated largely from chlorite, probably as a result of interaction with epidote or sometimes calcite (compare Tilley, 1923, pp. 187, 197). On the other hand, chlorite is quite absent from the " riebeckite "-schist, though its former presence, together with muscovite, may be inferred from the presence of plentiful biotite. The " riebeckite " appears almost certainly to have been formed at the expense of the highly ferruginous epidote with which it is always associated, possibly by reaction with the surrounding albite (compare Phillips, 1930, p. 252).

According to Murgoci (1905, pp. 143, 144) the conditions essential for the formation of riebeckite in igneous rocks are pressure and long-continued action of pneumatolytic vapours. Similarly Phemister (1926, pp. 34, 35) finds, in the case of the alkali-syenites of Loch Ailsh, that while some of the " riebeckite " of these rocks is primary, a great deal of it has been formed from aegirine-augite by the action of mineralising solutions, probably prior to complete consolidation of the rock. In the " riebeckite "-schist of the Haast Valley local sericitisation of albite and the presence of widely disseminated grains of pyrite and coarse apatite all point to pneumatolytic action during the later stages of metamorphism. Whereas tourmaline and apatite are constantly present and sometimes abundant in the quartz-plagioclase-biotite-schists and green amphibole-schists of this locality, pyrite is absent from these rocks, and the feldspars are typically clear and unaltered. It is thus apparent that the " riebeckite "-schist has been subjected to special pneumatolytic conditions which have not affected the associated rocks, and which may therefore constitute the essential factor upon which crystallisation of " riebeckite " instead of blue-green amphibole is dependent. The source of the mineralising vapours doubtless lies in the subjacent mass of granite, which from other considerations appears to underlie this particular area at no great depth.

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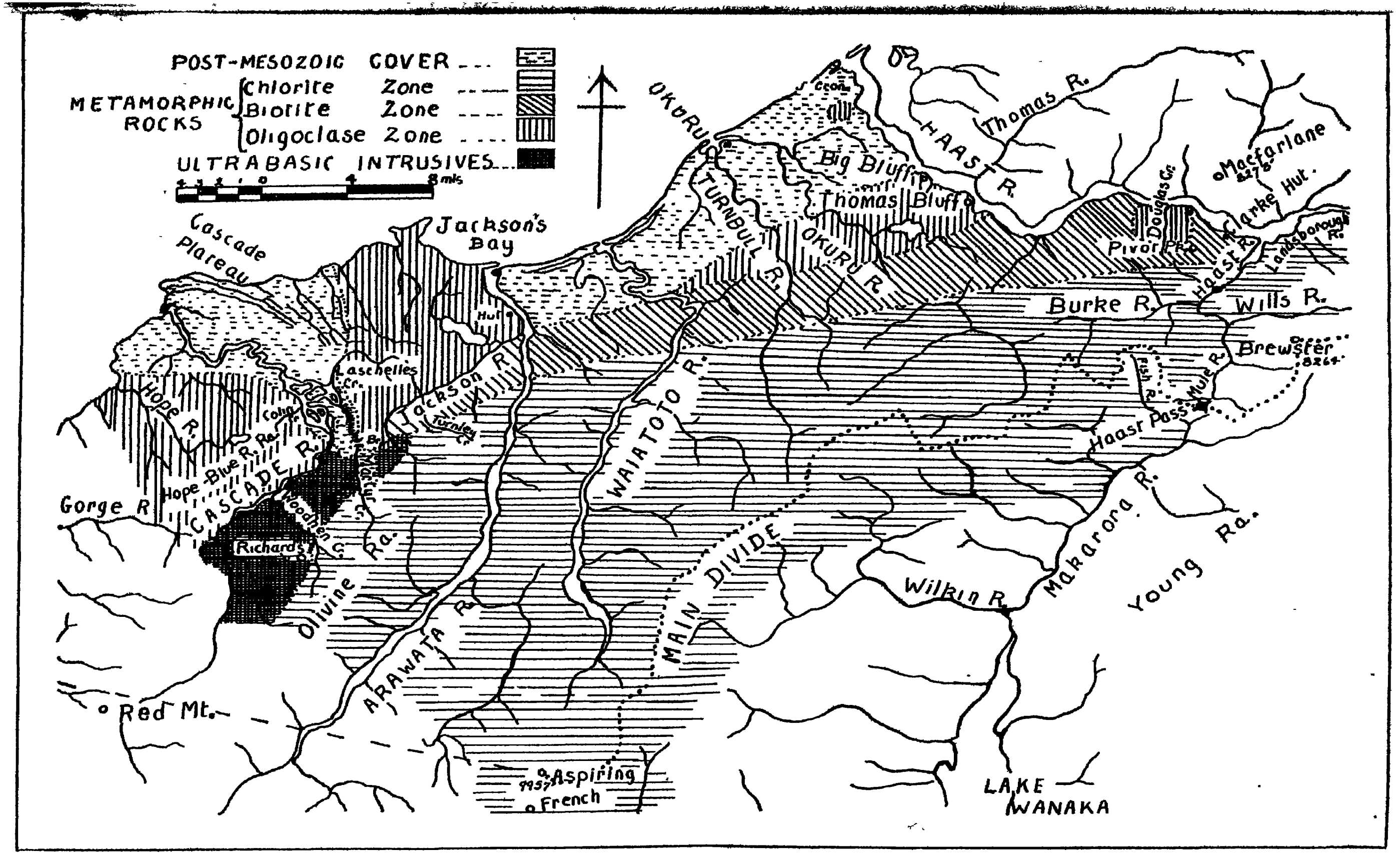
* A riebeckite-bearing schist of sedimentary origin has been described by W. E. Tarasenko ("On Some Crystalline Schists in the Krivoy-Rog Ore-bearing District," *Acta Universitatis Voronegiensis*, Voronezh, vol. 1, pp. 265-289, 1925).



Map showing the distribution of the metamorphic rocks and ultrabasic intrusives of Southern Westland.

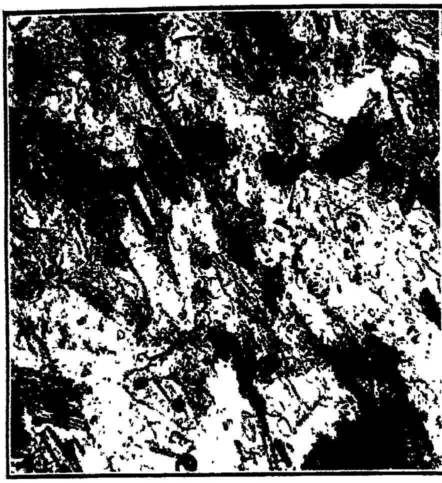


FIG. 1.—*Quartz-albite-chlorite-schist (No. 1304)*, with abundant prismatic epidote and patches of dusty magnetite.

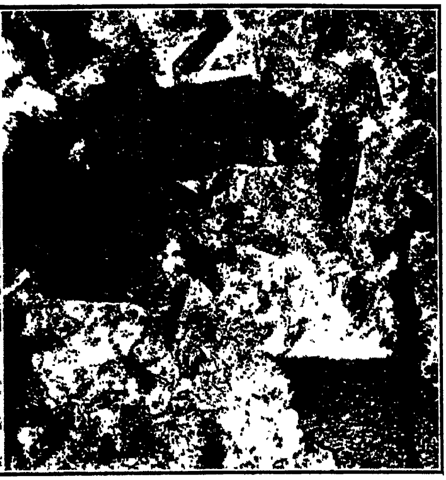


FIG. 2.—*Quartz-oligoclase-biotite-schist (No. 1288)*, showing irregular porphyroblasts of biotite, prisms of clinozoisite and colourless quartz and plagioclase.

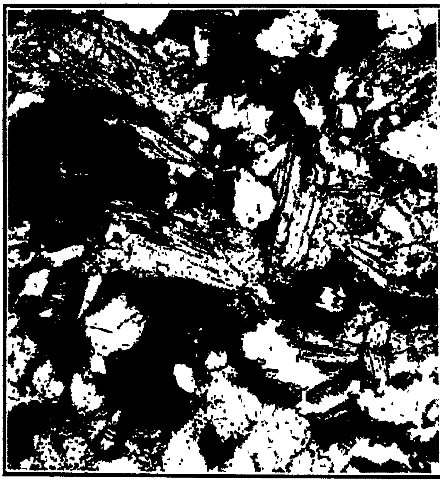


FIG. 3.—*Coarse-grained gneiss (No. 1278)*, with plentiful biotite and muscovite, quartz, and andesine.

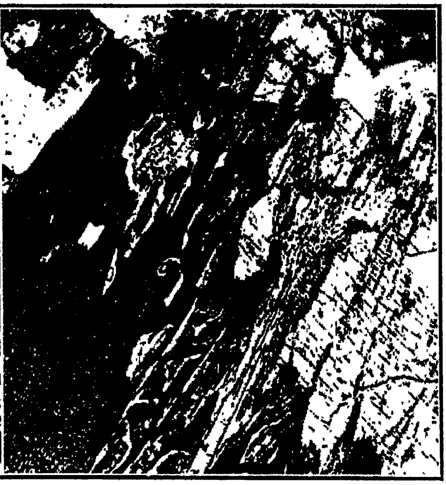


FIG. 4.—*Intergrowth of vermicular quartz and biotite in coarse-grained composite gneiss (No. 1338a)*, Note also the partial replacement of the large crystal of feldspar by sericitic mica.

All magnifications 37 diameters.

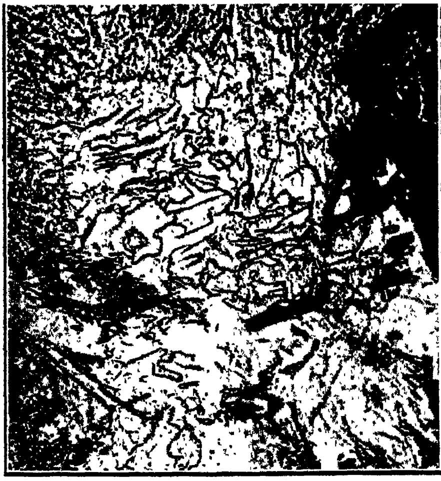


FIG. 5.—*Intergrowth of quartz and muscovite in coarse-grained composite gneiss (No. 1338a).*

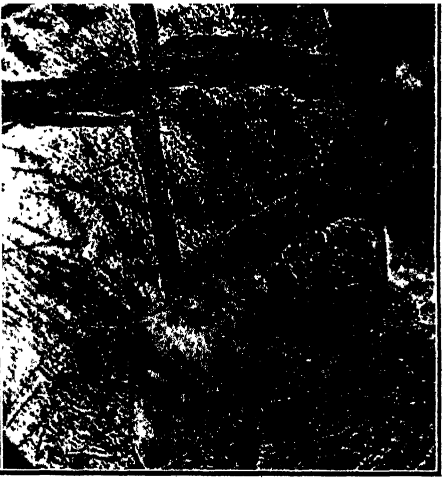


FIG. 6.—*Coarse-grained gneiss (No. 1338a),* showing development of sericite along cracks traversing coarse plagioclase. The highly irregular crystal interstitial to the feldspar is quartz.

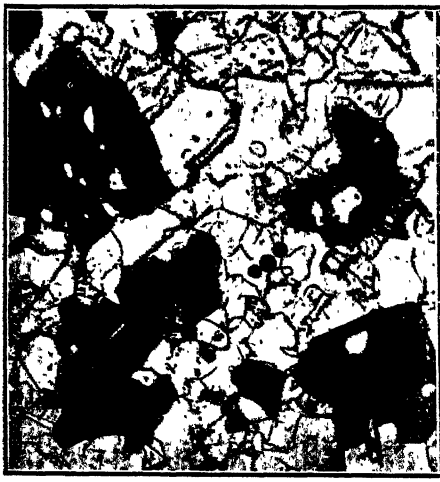


FIG. 7.—*Porphyroblastic hornfelsic paragneiss (No. 1349),* showing large crystals of biotite sieved with small inclusions of quartz and muscovite.

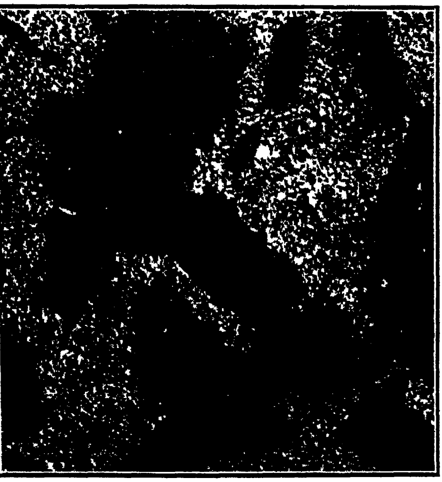


FIG. 8.—*Micaceous band in porphyroblastic hornfelsic paragneiss (No. 1345).* Large sieved crystals of biotite are enclosed in a fine-grained groundmass of muscovite and quartz.

All magnifications 37 diameters.

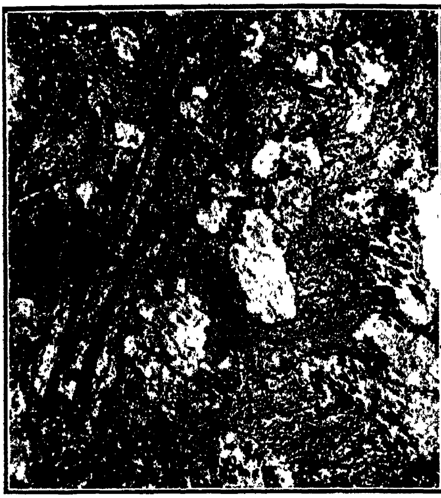


Fig. 9.—*Chlorite-calcite-albite-epidote-schist (No. 1318)*, showing coarse calcite, abundant chlorite, and irregular clear grains of albite with dark inclusions of epidote.

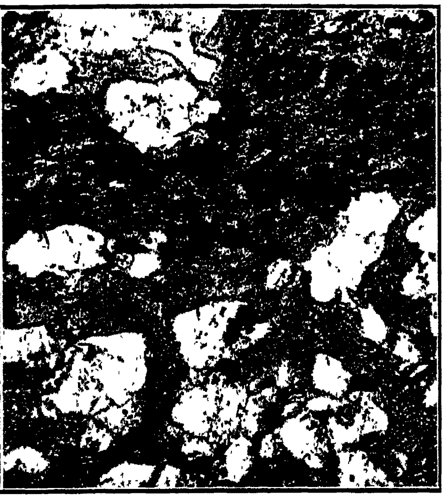


Fig. 10.—*Chlorite-albite-schist (No. 1319).* Note the abundant dark inclusions (consisting of granular sphene and iron ore) enclosed in some of the chlorite areas.

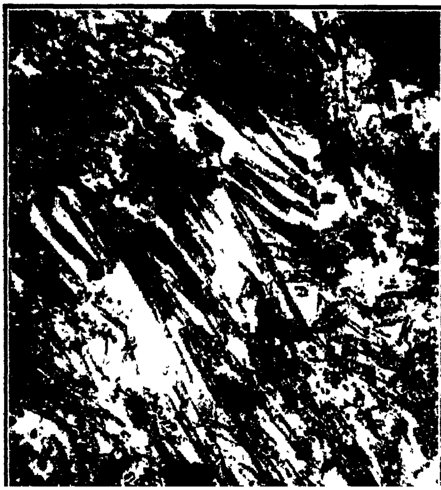


Fig. 11.—*Deep blue-green amphibole in amphibole-schist (No. 1287).*

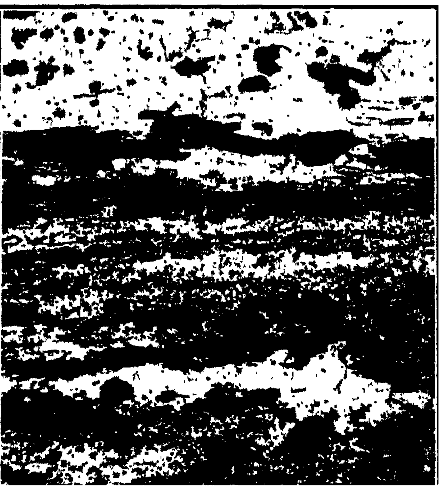


Fig. 12.—*Magnetite-haematite-schist (No. 1317).*

All magnifications 37 diameters.

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The Metamorphic and Intrusive Rocks of Southern Westland.

Part II.

By F. J. Turner, Otago University.

DISCUSSION OF THE METAMORPHIC PROCESS.

Progressive Metamorphism.

Establishment and Definition of the Metamorphic Zones: In his pioneer work upon progressive metamorphism in the Scottish Highlands, Barrow (1893 and 1912) established a sequence of metamorphic zones based upon the mineralogical changes observed to take place in sediments of pelitic composition, with gradually increasing metamorphism. Each zone was named after an index mineral, the first appearance of which defined the outer limit of the zone in question. The more recent investigation of Tilley (1925a) upon rocks south-west of the area studied by Barrow were also confined mostly to pelitic rocks. Tilley accepted the sequence of zones put forward by Barrow in 1912, except that he included the two outermost zones (Barrow's zones of clastic mica and digested clastic mica respectively) in a single zone characterised by chlorite. Modern workers (e.g., Tilley, 1925a; Elles and Tilley, 1930) now recognise for pelitic or psammo-pelitic rocks six zones characterised respectively by the following index minerals, in order of increasing metamorphic grade: chlorite, brown biotite, almandine, staurolite, kyanite, sillimanite. It is generally recognised, however, (e.g., Elles and Tilley, 1930, p. 622) that staurolite is formed only under rather special circumstances, so that the staurolite zone is not as clearly defined as the other five.

The effects of progressive metamorphism upon the green beds of the Scottish Dalradian have also been worked out recently (Phillips, 1930), and the mineral associations characteristic of all zones from that of chlorite to the kyanite-sillimanite boundary, as defined for pelitic rocks, have been determined.

From the petrological details given in the previous pages it is apparent that the rocks of the area between the Haast and Cascade Rivers also furnish an example of progressive metamorphism on a regional scale. Pelitic rocks are only rarely developed, however, and cannot therefore be used as the basis for zoning. By far the greater portion of the schists and gneisses of this region are of the quartzo-feldspathic type, derived ultimately from sandstones and grits of greywacke composition, and characterised by abundant quartz and sodic plagioclase, together with constant but small amounts of mica or chlorite. An attempt has therefore been made to establish a sequence of zones based upon the effects of progressive metamorphism of the quartzo-feldspathic rocks. In a later section the probable correlation with the zones as defined by Barrow and Tilley for pelitic rocks will be discussed.

In the Haast-Cascade area three zones are recognisable on this basis, and are characterised respectively by chlorite, biotite, and oligoclase. This sequence of zones is thus somewhat comparable with that established by T. Vogt (1927) for the progressively metamorphosed sediments of the Sulitelma area of Norway. The indices of Vogt's zones are chlorite, biotite, almandine, and oligoclase.

Distribution of Metamorphic Zones: The approximate positions of the isograds which limit the three zones recognised above, as deduced from examination of several extensive critical sections, are shown upon the accompanying map. These lines are no more than approximations, since their exact determination would involve some months of additional field work in exceedingly difficult and inaccessible country.

The zone of chlorite occupies the greater part of the map, and continues south-east beyond its limits for many miles into the great belt of schists of low metamorphic grade, which underlie Central Otago and constitute the Maniototo Series of Professor Park. In the north-east corner of the area mapped, however, the complete chlorite zone is limited to a width of about 10 miles. Here there is relatively rapid transition from coarse quartz-albite-chlorite-schists near the biotite isograd, through the phyllites of the upper Haast Gorge, to slates, which appear in the vicinity of Haast Pass and are the least metamorphosed rocks of the chlorite zone.

The biotite zone constitutes a narrow belt of schists which flank the rocks of the chlorite zone on the north-west. They are well exposed along the southern side of the Haast Valley, between Thomas Bluff and the Landsborough Junction, and may also be observed on the south-eastern side of the Jackson Valley. In this latter locality the biotite zone is not fully developed, but is cut off sharply on the north-west by the Cascade-Jackson Valley Fault, which here constitutes the boundary between the zones of biotite and oligoclase.

The typical feldspar of the biotite zone, as defined above, is albite containing 5% to 7% of anorthite. As the metamorphic grade increases the plagioclase becomes richer in anorthite until the composition of oligoclase ($Ab_{90}An_{10}$ to $Ab_{70}An_{30}$) is attained. An oligoclase isograd has therefore been drawn, marking the first appearance of feldspar containing 10% of anorthite, and an oligoclase zone is recognised, including the area occupied by oligoclase-biotite schists, hornfelses, and gneisses. In those portions of the oligoclase zone where metamorphism has been most intense—e.g., the area of gneisses one mile inland from Mr J. Cron's homestead, near the mouth of the Haast River—basic oligoclase, oligoclase-andesine, and even in one case andesine of composition $Ab_{60}An_{40}$ may be developed. Normally, however, the composition of the feldspar of the oligoclase zone lies between $Ab_{90}An_{10}$ and $Ab_{80}An_{20}$.

The zone of oligoclase forms a wide belt of intensely metamorphosed rocks lying north-west of the biotite zone and stretching right to the coast. In the Haast Valley section the oligoclase isograd cuts the valley on its south side, not far east of Thomas Bluff, and from this point to the sea within the oligoclase zone there is a steady increase in intensity of metamorphism. Ten miles east of Thomas

Bluff, however, there is a small isolated area in the vicinity of Douglas Creek which certainly lies well within the oligoclase zone, for the feldspar varies from medium oligoclase to oligoclase-andesine. The exact limits of this area have not been determined, but its approximate extent is indicated on the map.

The rocks of the oligoclase zone are also developed in considerable variety in the south-western portion of the map, between the sea coast and the Cascade-Jackson Valley Fault, which has here brought them into juxtaposition with some of the less metamorphosed of the schists of the biotite zone. Transition between the two zones, such as may be seen in the Haast Valley section, is therefore not apparent in this southern area. Indeed, the abrupt change in metamorphic grade at the outcrop of the fault is so conspicuous that in an earlier paper (Turner, 1930, p. 186) the rocks of the oligoclase zone (north-west of the fault) were provisionally separated as a distinct series from the quartz-albite-biotite-schists and the schists of the chlorite zone to the south-east.

MINERALOGICAL AND TEXTURAL CHANGES INVOLVED.

(a.) *In the Quartzo-feldspathic Rocks:* In order of increasing metamorphic grade the rocks of the quartzo-feldspathic group lying within the chlorite zone have been classed as slates, phyllites, and quartz-albite-chlorite-schists. The most conspicuous effects of progressive metamorphism within the limits of the zone concern the structure and texture of the rocks, rather than the nature of the component minerals which constitute a remarkably constant assemblage of quartz, almost pure albite, delessitic chlorite, muscovite, and epidote in varying proportions. During the transition from slate to fully crystallised quartz-albite-chlorite-schist, the average grain-size increases rapidly from about 0.01 mm. to between 0.1 mm. and 0.5 mm., and at the same time the foliation becomes gradually more pronounced. One of the first definitely metamorphic minerals to crystallise is tourmaline, which appears as scattered relatively large idioblastic prisms in even the most finely crystalline slates, and remains as a constant accessory in the more highly metamorphosed schists. The white mica of the slates, as observed by Brammall (1921, pp. 212, 213) in the case of Bolivian rocks, is a distinctly greenish, rather poorly birefringent variety. In the phyllites and schists this mineral gradually loses its green colour, and the birefringence increases to that of a typical muscovite, though the optic axial angle may sometimes remain abnormally small. An unusual feature is the development of actinolite at an early stage in one of the phyllites (No. 1290) much as in some of the green schists of the chlorite zone. A gradual diminution in the amount of epidote is apparent in the transition from slate to schist, but this is probably due rather to differences in original composition of these rocks than to progressive metamorphism.

Transition from the zone of chlorite to the biotite zone is marked by the incoming of brown biotite, as a result of reaction between muscovite and chlorite, much as described by Tilley (1926, p. 40) for schists of pelitic composition. Chlorite is therefore usually absent or present in small amount, though in rare cases (e.g., No. 1288), where there was an initial deficiency in muscovite, considerable quantities of chlorite may survive even into the oligoclase zone. Where it first appears the biotite is pale yellowish to deep golden brown (e.g., No. 1325), and is developed as scattered knots upon the foliation planes; but as the metamorphic grade increases the mineral becomes much more plentiful, and the colour for vibrations parallel to Z changes first to deep sepia and finally, near the oligoclase isograd, to dark reddish brown. As a result of reaction with epidote the feldspar of the biotite zone is typically considerably more calcic than in the zone of chlorite. It ranges from nearly pure albite (e.g., No. 1283, one mile east of Thomas Bluff, Haast Valley) to albite-oligoclase, but usually contains about 7% of anorthite. Epidote is always present in rather diminished amounts, and is always a poorly birefringent type approaching clinozoisite, in contrast with the often highly ferriferous epidote of the chlorite zone. In the transition from the chlorite to the biotite zone textural changes are not conspicuous. In general the grain-size of the biotite-schists is much the same as that of the quartz-albite-chlorite-schists, but the foliation is more perfectly and regularly developed than in these latter rocks.

The rocks of the oligoclase zone include biotite-hornfelses, biotite-andalusite-hornfels, hornfelsic paragneisses, composite gneisses, and the more strongly metamorphosed of the quartz-plagioclase-biotite-schists.

The transition from the zone of biotite to that of oligoclase is best observed in the continuous section along the southern side of the Haast Valley. The schists of Thomas Bluff (No. 1282), lying just within the oligoclase zone, are distinguished from those further east (e.g., No. 1283) by the fact that the anorthite content of the feldspar has now reached 10%, while the biotite is somewhat coarser, and is definitely dark reddish brown for light vibrating parallel to Z. The rocks of Big Bluff (Nos. 1280, 1281), three or four miles west of Thomas Bluff, are coarse gneisses which lack the perfect fissility of the schists further east, and contain oligoclase of medium composition. The most advanced stage of metamorphism is shown by gneisses (e.g., Nos. 1278 and 1279) collected about one and a-half miles from the mouth of the Haast River. The foliation of these rocks is now rather imperfectly developed in comparison with that of the schists of Thomas Bluff. The grain size is consistently coarse, averaging about 0.3 mm. to 1 mm. for quartz and feldspar and from 0.5 mm. to 1.5 mm. for the micas. The anorthite content of the feldspar has reached from 33% to 40%, indicating that a high grade of metamorphism has been attained, while epidote is absent, having been completely used up in production of andesine from more sodic feldspar. The gneisses between Big Bluff and the mouth of the river frequently show such features as development of myrmekite or introduction of orthoclase, coarse apatite, and coarse muscovite, all of which are believed to be due to the influence of invading pegmatites, and for this reason they have been grouped with the composite gneisses. These effects are much less pronounced, though more widely and regularly distributed, than in the Cascade-Arawata area further south.

In this latter locality the rocks of the oligoclase zone are again distinguished by the presence of oligoclase and intensely pleochroic reddish brown biotite, and by absence of epidote and chlorite, except as products of later retrogressive metamorphism. In texture, however, they differ conspicuously from the schists and gneisses of the Haast Valley, since they have been subjected to the hornfelsing action of a subjacent mass of granite which invaded the rocks of this southern area during their metamorphism, but which did not similarly influence the rocks north of Okuru. In the south-western part of the oligoclase zone, therefore, such features as granoblastic texture, porphyroblastic texture, and sieve-structures (especially in the case of biotite) are extremely characteristic. A further peculiarity of the oligoclase zone as developed in the Cascade and Arawata Valleys is the local restricted formation of composite gneiss as a result of the influence of invading dykes of pegmatite. In an earlier section the mineralogical and textural changes characteristic of this intrusive phase of the metamorphism have been fully discussed, and it has been pointed out that these changes were effected under conditions of high-grade metamorphism, i.e., while the rocks in question still lay within the zone of active formation of oligoclase.

(b.) *In the Micaceous Schists:* Bands of highly micaceous schist representing initial sediments of pelitic composition were only rarely observed. With the exception of mica-rich laminae and thin bands in the hornfelsic paragneisses of the Cascade Valley, they include a single specimen from the chlorite zone, and several from the zone of oligoclase. Judging from these, however, the mineralogical changes involved in their progressive metamorphism are much the same as in the case of the quartzo-feldspathic rocks.

(c.) *In Green Schists:* The green schists occurring within the chlorite zone include chlorite-albite-epidote-schists and chlorite-calcite-albite-epidote-schists, which occur mainly as plentiful boulders in the Jackson River and its eastern tributaries, and have doubtless been derived from a source not far outside the biotite isograd, along the range which flanks the Jackson Valley on the south-east. The feldspar of these rocks is albite with an anorthite content below 5%, and the mica, when present, is always muscovite. In specimens of chlorite-schist from Central Otago (Clyde, Queenstown, and the Kawarau Gorge)—well within the limits of the chlorite zone as defined above—golden brown biotite has developed, however, as scattered patches along the planes of foliation. This early appearance of biotite in the progressive metamorphism of muscovite-bearing green schists has been commented upon by Tilley (1925a, p. 103) and Phillips (1930, pp. 244, 245) in the case of the green beds of the Scottish Dalradian. Pale green or colourless actinolite, though not common, is sometimes developed in small amounts in rocks of the chlorite zone (e.g., No. 1319), though strongly coloured amphiboles are confined to rocks of considerably higher metamorphic grade. This agrees with the observations of Tilley (1923, p. 185) and

Phillips (1930, p. 253) upon the green schists of the Start area and the Scottish Dalradian respectively. The epidote of the chlorite zone is nearly always a highly ferruginous type with a birefringence varying from 0.035 to 0.040.

Though collected only from boulders in the Jackson River and its tributary, Turnley Creek, the biotite-calcite-albite-epidote-schist No. 1326 and the amphibole-schists Nos. 1312 and S.W. 19 may be assumed with reasonable certainty to have been brought down from localities lying within the zone of biotite on the range which flanks the Jackson on the south-east. The metamorphic grade of the schists in question is obviously higher than that of the chlorite-schists, while their perfect schistosity excludes the possibility of origin among the hornfelsic rocks, which in this area are developed over the whole of the oligoclase zone.

One of the first minerals to appear within the biotite zone is biotite itself—a deep golden brown to pale yellow variety, lacking the intense red-brown colour so characteristic of the biotite in the more highly metamorphosed of the quartzo-feldspathic rocks. As would be expected, however, from the comparative rarity of muscovite in the green schists of the chlorite zone, biotite is usually present in accessory amount only, in the corresponding rocks of the zone of biotite. In one case, however, this mineral makes up 25% of the rock (No. 1326), indicating admixed argillaceous material in the initial unmetamorphosed rock. As with the quartzo-feldspathic rocks, the feldspar is noticeably more calcic in the zone of biotite, the composition varying from medium albite ($Ab_{95}An_5$) to oligoclase-albite ($Ab_{90}An_{10}$). The anorthite content appears actually to be slightly higher than in isogradic quartzo-feldspathic schists. An amphibole of the actinolite-glaucophane series, having deep greenish blue absorption for light vibrating parallel to Z, first appears in the biotite zone and becomes increasingly abundant as metamorphism becomes more intense. There appears to be complete transition from almost colourless actinolite (of the chlorite zone), through rather pale amphibole, to the intensely pleochroic actinolite-glaucophane, which appears to be characteristic of the more metamorphosed rocks of the biotite zone and the schists belonging to the zone of oligoclase. In all these cases the amphibole appears from its constant close association with chlorite to have arisen mainly by reaction between chlorite and epidote or calcite, much as described by Tilley (1923, pp. 187, 197) in the schists of the Start area. It is probable, however, that the glaucophane molecule, which enters into the composition of the blue-green amphibole, owes its presence to some such reaction involving albite, as that given by Phillips (1930, p. 252): epidote + albite $\longrightarrow$ amphibole + more calcic plagioclase.

The most intensely metamorphosed members of the green schist group are Nos. 1287 and 1291, which appear to have been derived from either just within or just outside the oligoclase isograd. The anorthite content of the plagioclase is 10% in one case and 12% in the other, indicating that the source of the rocks probably lay just inside the zone of oligoclase. The amphibole is now very strongly coloured, and is so plentiful as to impart a nematoblastic texture to the rock in some instances. A noticeable feature is the relatively low iron content of the epidote, which has become progressively poorer in iron during transition from the zone of chlorite to that of oligoclase. In specimens Nos. 1287 and 1291 the percentage of the clinozoisite molecule present in the epidote is about 90%. The actual quantity of epidote has also diminished considerably, as a result of its having been used up during the formation of amphibole and anorthite.

Grades of Metamorphism Attained in the Three Zones: In the following paragraphs an attempt will be made to estimate the degree of metamorphism reached in each of the three zones, which may thus be compared with the standard metamorphic zones as defined for pelitic schists of the Scottish Highlands.

The literature dealing with the progressive metamorphism of the schists of the Scottish Dalradian contains many references to quartzo-feldspathic rocks, in some of which sodic plagioclase is one of the main constituents. Nevertheless details of the mineralogical changes which have taken place during the progressive metamorphism of such rocks, and accurate correlations of these with the changes occurring in pelitic schists under similar conditions have seldom been recorded.

One of the best known accounts is that given by Cunningham-Craig (1904), who describes in detail the progressive metamorphism of the Ben Ledi Grits in the Loch Lomond area, where recrystallisation (constructive metamorphism) has followed closely upon destructive or dynamic metamorphism due to shearing during intense folding. In order of increasing constructive metamorphism four zones are recognised:—

(1) The zone in which grits predominate.
(2) The zone of mica-schists in which, owing to their resistance to initial dynamic metamorphism, a few of the coarser grits still survive.
(3) The zone of mica-schists composed entirely of authigenic minerals.
(4) The zone of coarse albite-gneisses.

In the first and second zones (Cunningham-Craig, 1904, pp. 17-21) biotite—believed by Cunningham-Craig to be authigenic—is plentiful in the Ben Ledi Grits; but in the second and third zones this mineral becomes progressively chloritised, while the coarse albite-gneisses typically contain no biotite, the place of which is taken by chlorite and muscovite. The stable mineral association in the zone of albite-gneiss is thus albite-chlorite-muscovite, just as in the chlorite zone of South Westland, and it therefore appears unlikely that Cunningham-Craig is correct in his suggestion that the biotite of the less metamorphosed rocks is authigenic. The hypothesis has also been put forward (Cunningham-Craig, 1904, pp. 26-27) that the albite-gneisses of Loch Lomond are isogradic with garnetiferous schists and gneisses of the Ben Ledi group in the Aberfeldy district, and that the development of albite is a consequence of hydro-thermal metamorphism, while garnet has been generated under conditions of purely thermal metamorphism. More recently Bailey (1922, p. 92; 1923, pp. 326-327) adopted similar views. On the assumption that albite and garnet are antipathetic, this writer recognises in the Cowal area three zones according to the following scheme:—

1. Mica inconspicuous.
2. Mica conspicuous.
3. (a) Mica with garnet.
   (b) Mica with albite.

Bailey's views in this connection have, however, been severely criticised by Tilley (1925, pp. 108, 112), who states that the albite-gneisses of Loch Lomond owe their mineralogical composition to peculiarities in the initial chemical composition, and maps them as lying well within the zone of biotite.

Following Tilley's mapping, it must still be admitted that in rocks of the albite-gneiss type originating from greywackes or greywacke-shales (Bailey, 1923, p. 325), biotite develops considerably later than in schists of pelitic composition. The chlorite-muscovite association is therefore stable well within the biotite zone as defined for pelitic rocks.

In southern Westland the biotite isograd, drawn on the accompanying map, marks the first appearance of biotite in rocks which resemble in mineral composition and origin the albite-gneisses of the Loch Lomond area. The " chlorite zone " of Westland and Otago is therefore equivalent, as regards the metamorphic grade attained therein, to the chlorite zone and part of the zone of biotite, as defined for pelitic rocks in the Scottish Highlands.

In the schists of southern Westland the most conspicuous mineralogical change induced by regional progressive metamorphism, once biotite has fully developed, is a gradual change in composition of the plagioclase. As a result of reaction with epidote this mineral becomes more calcic as the grade of metamorphism rises. The anorthite content of the plagioclase may therefore be taken as index of intensity of metamorphism, provided the mineral is in equilibrium with excess of epidote. This last qualification is important, since when once the epidote has been used up in the reaction the composition of the plagioclase remains constant during progressive metamorphism beyond this point. It is therefore evident that a rock such as No. 1329, containing feldspar of composition $Ab_{93}An_7$, but no epidote, is not necessarily of lower grade than one in which basic oligoclase and epidote are in mutual equilibrium. In general the rocks in which the composition of the plagioclase may serve as a metamorphic index must therefore be rich initially in both plagioclase and epidote. Such rocks include many green schists and certain of the schists of greywacke composition, e.g., most of the quartzo-feldspathic schists of South Westland.

A detailed account of the changes in composition of plagioclase which take place during the progressive metamorphism of green schists has recently been given by Dr. Phillips (1930, pp. 247-250) in his description of the green beds of the Scottish Dalradian. Within the chlorite zone (as defined for pelitic schists) the anorthite content never rises above 3% to 4%. " The anorthite molecule only begins to enter noticeably into the composition of the plagioclase when the garnet isograd is passed. Measurements of material from localities around West Loch Tarbert, Loch Fyne, and south of Aberfeldy (all well within the garnet zone) give compositions of $Ab_{95}An_5$ to $Ab_{90}An_{10}$. As the grade increases farther the plagioclase is taking part actively, and the composition changes rapidly. The most calcic feldspars measured occur near the summit of the Hill of Strone, south-west of Glen Clova, near the kyanite-sillimanite boundary, with a composition of $Ab_{63}An_{37}$, medium andesine. At the north-east side of Glen Clova, near Loch Brandy, the average composition of a large number of measurements was $Ab_{68}An_{32}$" (Phillips, 1930, p. 258).

In applying these results to the quartzo-feldspathic schists of southern Westland it must be remembered that the ultimate chemical and mineralogical compositions of the two groups of rocks in question are not the same. In each case the reaction involving the production of more basic plagioclase from albite may be expressed in part by the following relation: albite + epidote ⟶ more calcic plagioclase.

There appear to be three cases, however:—

(1) In the case of the Dalradian green beds the reaction is essentially bound up with the production of hornblende, and has been expressed by Phillips (1930, p. 252) by the relation: epidote + albite ⟶ amphibole + more calcic plagioclase.

(2) It has already been shown that in the green schists of Westland, while the above reaction may account for the formation of the glaucophane component of the characteristic blue-green amphibole, the latter mineral appears to have been developed mainly by interaction between chlorite and either epidote or calcite. The full reaction may thus be written: chlorite + epidote + albite ⟶ amphibole + more calcic plagioclase. This does not differ greatly from the reaction given under (1).

(3) During progressive metamorphism of the quartzo-feldspathic schists of Westland the low-grade association albite-chlorite-epidote-muscovite passes over to the high-grade assemblage oligoclase-biotite-muscovite. The two reactions involved are: chlorite + muscovite ⟶ biotite; and albite + ferriferous epidote ⟶ oligoclase + iron (which presumably enters into the biotite). It is, of course, conceivable that production of increasingly calcic plagioclase by this reaction would not follow a course exactly parallel with reactions (1) and (2), though, since the composition of plagioclase is known to be sensitive to changes in metamorphic grade, the divergence is not likely to be large. In support of this latter contention it may again be pointed out that the green schists of southern Westland, throughout their range from the zone of chlorite to just beyond the oligoclase isograd, contain plagioclase of approximately the same composition as isogradic quartzo-feldspathic schists.

In the Haast-Cascade area the composition of the plagioclase ranges from $Ab_{95}An_5$ to $Ab_{90}An_{10}$ in the zone of biotite, and from $Ab_{90}An_{10}$ to $Ab_{60}An_{40}$ in the oligoclase zone. If these figures are compared with the compositions determined by Phillips for the Dalradian green beds, and due allowance is made for the possibility that in the latter case the anorthite content of the plagioclase may increase more slowly than in the case under consideration, it must still be admitted that the rocks of the oligoclase zone of Westland are of high metamorphic grade. The writer therefore suggests that the inner part of the biotite zone and a considerable portion of the oligoclase zone of Westland may be regarded as metamorphically equivalent to the zone of almandine as defined for pelitic rocks in the Scottish Dalradian. The relatively basic plagioclase (sodic to medium andesine), which is characteristically a constituent of the highly metamorphosed gneisses in the vicinity of the mouth of the Haast River, points to the possibility that these rocks may even be isogradic with those of the staurolite or kyanite zones of Scotland. This conclusion is borne out by the presence of sillimanite in some of the more intensely metamorphosed gneisses of the oligoclase zone.

The amphibole-schists Nos. 1287 and 1291 which occur in the vicinity of the oligoclase isograd show certain features, in addition to the presence of sodic oligoclase, indicating a metamorphic grade comparable with that of the garnet zone of Scotland. These rocks contain plentiful blue-green strongly coloured amphibole in association with from 10% to 15% of brown biotite. In his account of the Start green schists, Tilley (1923) records that while pale or colourless hornblende is abundantly developed within the zone of chlorite in the absence of muscovite, when the latter mineral is initially present, hornblende appears only at a later stage in metamorphism after the formation of biotite. Phillips (1930, pp. 252-253) comes to a similar conclusion in the case of Dalradian green beds, and states: "In the non-potassic green schists of the Start, South Devon, as in the altered spilites of Cornwall and Finland, hornblende appears before biotite. With admixed sericitic material, as in a tuff or derived sediment of the nature of the green beds, the higher potash-content leads to the formation of biotite, and hornblende appears much later often after garnet. . . . In this connection material from localities in the Loch Earn district . . . although occurring in the middle of the chlorite zone of pelitic rocks, shows the development of amphibole. The mineral is finely fibrous, pale green or almost colourless (lacking the characteristic blue-green axial tint of the hornblende of higher-grade rocks . . . A bulk analysis of one of these rocks is given, and shows a molecular ratio for CaO to K_2O of 27, this ratio for the Cowal rock (biotite-epidote-albite-schist) being only 8. An alkali estimation of the other Loch Earn rock showed a K_2O content of only 0.41." The association of abundant strongly pleochroic blue-green amphibole, brown biotite, and acid oligoclase in the amphibole-schists of Westland is thus almost exactly comparable with the assemblage of minerals typical of green schists of the garnet zone in the Scottish Dalradian, except that garnet itself is absent in the former case.

This conclusion is strongly supported by Vogt's (1927) researches, which show clearly that in the Sulitelma rocks anorthite enters notably into the plagioclase only within the zones of almandine and oligoclase. In the sedimentary schists of Vogt's zone of oligoclase the anorthite-content of the plagioclase is 20% to 34%, while in the green schists of the epidote-amphibolite-facies (isogradic with those of the zone of almandine) this figure is only 10% to 26%.

A singular feature which calls for some explanation is the complete absence of garnet from both quartzo-feldspathic and green schists in the higher zones of metamorphism in the Haast-Cascade area. The mineral occurs only in a single specimen of unusual composition—the garnetiferous quartz-magnetite-haematite-schist represented by sections Nos. 1316 and 1317.

The genesis of almandine garnet in regionally metamorphosed sediments has recently been discussed by Tilley (1926, pp. 41-44), who concludes that within the almandine zone it is formed from chlorite, often with exchange of magnesia for ferrous oxide. Where manganese is present spessartite-almandine forms at an even earlier stage of metamorphism, while the presence of lime also appears to favour early genesis of garnet, into which the grossularite molecule may enter to a not unimportant extent.

During progressive metamorphism of the quartzo-feldspathic schists of southern Westland, chlorite is almost invariably completely used up in the production of biotite before the zone of oligoclase is reached. Beyond the oligoclase isograd these rocks contain biotite and excess muscovite, but no chlorite such as might give rise to garnet, except in such rocks as the chlorite-hornfelses, where chlorite has subsequently developed from biotite by retrogressive metamorphism. The composition of the quartzo-feldspathic rocks is therefore sufficient in itself to account for the non-appearance of almandine within the zone of oligoclase.

The same reasoning applies also to the rocks grouped as micaceous schists. Where these occur within the zone of oligoclase they contain abundant biotite and a plentiful excess of muscovite, so that almandine (accompanied by orthoclase) could arise only by interaction between biotite and quartz, a reaction which, according to Tilley (1926, p. 44), is restricted to the highest grades of metamorphism well beyond the zone of almandine.

The case of the green schists is different, however. Chlorite is still present even in rocks occurring near the oligoclase isograd, but is gradually used up in the production of blue-green amphibole, not of garnet. Except for the complete absence of this latter mineral, the assemblage of minerals in the Westland green schists corresponds exactly with the association typical of the Dalradian green beds where these lie within the almandine zone. Of these rocks Phillips (1930, p. 252) writes: "It has been noted that garnet has been sporadically developed . . . The variable degree to which excess of chlorite survives and recrystallises in higher zones may be correlated with this variability of occurrence of garnet." In the case of the Westland schists no such explanation can be advanced.

Tilley (1926a) has also shown that the nature of the metamorphic process has a profound influence upon the crystallisation of garnet. Almandine is typically absent from the thermal assemblages of large-scale contact zones such as those of Kristiania and Comrie, though when manganese is present spessartite forms readily enough in contact aureoles. In cases where almandine-schists have been subjected to thermal metamorphism, the garnet is unstable, and breaks down to cordierite and magnetite.

It will be shown in a later section that there is considerable evidence to indicate that the intrusion of a subjacent batholith of granite was one of the essential factors in the metamorphism of the Haast-Cascade area of Westland. The influence of magmatic fluids and of high temperature induced by this invading mass appear to have been very far-reaching, and undoubtedly extended into the outer part of the zone of chlorite. The writer therefore suggests that this "contact" influence has perhaps been a sufficiently important factor in the metamorphic process to render crystallisation of almandine impossible, even in rocks such as the green schists, the composition of which favoured its development. The fact that the garnet of the only garnetiferous schist (No. 1317) collected by the writer proved to contain plentiful manganese accords with this view in the light of Dr Tilley's observations.

The following table summarises the conclusions reached by the writer in comparing the metamorphic grade of the three zones of South Westland with that of the Scottish zones as defined for pelitic rocks.

Zones of South Westland.	Zones of Scottish Highlands.	Grubenmann's Depth Zones.
Chlorite.	Chlorite + outer portion of Biotite.	Epi-Zone.
Biotite.	Inner portion of Biotite + outermost portion of Almandine.	Meso-Zone.
Oligoclase.	Middle and inner portions of Almandine possibly + Staurolite and Kyanite.	

ADDITIONAL NOTE ON PROGRESSIVE METAMORPHISM OF GREEN SCHISTS.

Since the completion of this paper a detailed account of the progressive metamorphism of basic and basic-intermediate volcanic rocks of the Misaka Series of Japan has come to hand (K. Sugi, 1931[*]). The following brief comparison between Sugi's results and the present writer's observations upon the green schists of Westland has therefore been added.

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[*] "On the Metamorphic Facies of the Misaka Series in the Vicinity of Nakagawa, Prov. Sagami." *Jap. Jour. Geol. and Geogr.*, vol. IX, No. 1-2, 1931, pp. 87-142.

In the district studied by Sugi, schists belonging to four distinct facies have been formed by metamorphism of basic pyroclastic rocks:

(1) Greenschist-Facies. Essential constituents are albite (Ab_{98} to Ab_{90}, averaging Ab_{95}), ferriferous negative chlorite and highly ferriferous epidote, accompanied by minor leucoxene, and sometimes sericite, calcite, or quartz.

(2) Actinolite-Greenschist-Facies. Essential constituents are albite (Ab_{94} to Ab_{91}), actinolite, clinozoisite, and ferriferous epidote, accompanied by minor leucoxene, poorly ferriferous epidote, and quartz. The epidote is often zoned, the outer zones being rich in clinozoisite (p. 108).

(3) Transitional Facies. Essential constitutents are albite (Ab_{90}) and actinolite, with minor amounts of clinozoisite, pale chlorite, leucoxene, and quartz. Oligoclase-andesine (Ab_{70}) and green hornblende are developed to a minor extent, usually constituting distinct augen.

(4) Amphibolite-Facies. Essential minerals are basic plagioclase (Ab_{42} to Ab_{15}) and common green hornblende.

The less metamorphosed members of the Misaka Series resemble isogradic green schists of South Westland, in the gradually increasing anorthite content of the plagioclase, and decreasing iron content of epidote and chlorite (with resultant zoning in the case of epidote) as the grade of metamorphism advances. Actinolite is less commonly and biotite more usually developed in the Westland rocks than in those described by Sugi.

In the schists of the Misaka Series the anorthite content of the plagioclase is perhaps slightly higher than in the corresponding low-grade green schists described by the present writer. It will be noticed, however, that in the schists of the Amphibolite-Facies and the facies transitional to the Actinolite-Greenschist-Facies, as described by Sugi, the entry of coloured amphibole (green hornblende) is accompanied by very rapid rise in the anorthite content of the plagioclase. This feature is not parallel in the amphibole-schists of Westland, where deep blue-green amphibole of the actinolite-glaucophane series typically is associated with sodic oligoclase. The reason for this discrepancy lies partly in the somewhat lower metamorphic grade of the Westland rocks, and partly in the complex nature of the metamorphic process which affected the Misaka Series. According to Sugi (1931, pp. 139-142) the present mineralogical constitution of the rocks of the Greenschist and Actinolite Greenschist-Facies was determined by dynamic metamorphism assisted by the effects of minor intrusions of basic rocks, while the amphibolites, on the other hand, are products of subsequent purely contact action of a quartz-diorite intrusion upon the invaded green schists.

RETROGRESSIVE METAMORPHISM.

As was pointed out in the previous paper referred to (Turner, 1930a, p. 184), the final stage in the metamorphic history of the Cascade Valley was marked by minor retrogressive metamorphism, when the schists, gneisses, and hornfelses were subjected to conditions typical of Grubenmann's epi-zone. In some cases the result was more or less complete diaphthoresis involving the formation of characteristic low-grade rocks—the chlorite-hornfelses and certain contorted quartz-albite-muscovite-chlorite-schists. More commonly, however, only partial recrystallisation in localised patches of small extent has occurred, as in many of the biotite-hornfelses. As would be expected from the nature of the process, the effects of retrogressive metamorphism are most marked in rocks lying within the oligoclase zone. They are especially conspicuous in specimens collected from along the outcrop of the Cascade-Jackson Valley Fault, and in its immediate vicinity where shearing has been most intense. Breaking down of high-grade minerals to a low-grade association has proceeded further in rocks of small grain size (e.g., hornfelses) than in coarser rocks such as the gneisses of the same district. The latter have been affected mechanically, however, just as much as rocks of finer grain.

The effects of retrogressive metamorphism in the Haast-Cascade region have already been discussed in the sections dealing with the petrography of the chlorite-hornfelses, biotite-hornfelses, and contorted quartz-albite-muscovite-chlorite-schists, and compared with the observations of Eleanora Knopf (1931) upon diaphthoresis. A summary of the effects observed by the present writer may conveniently be given at this stage as follows:—

(1) One of the most easily detected and frequent changes observed is replacement of biotite by chlorite. The pseudomorphs often contain grains of sphene or needles of sagenetic rutile, representing the titanium content of the parent biotite.

(2) Plagioclase is often replaced by sericitic mica, either partially or completely. It should be noted, however, that in other cases sericitisation of plagioclase has occurred at an earlier stage during the formation of composite gneiss from hornfels, under the influence of pegmatitic solutions.

(3) In some of the hornfelses, epidote has been generated in small amounts at the expense of biotite, especially where these rocks are traversed by small shatter planes.

(4) In hornfelses and hornfelsic paragneisses containing andalusite (Nos. 1211, 1212, 1343) this mineral has been partially or in one instance (No. 1343) completely altered to "shimmer-aggregates" of sericitic mica.

(5) Mechanical effects of retrogressive metamorphism are often very pronounced even when mineralogical changes have not been effected. They include:—

(a) Production of undulose extinction in crystals of quartz, feldspar, and sometimes even mica.

(b) Bending of twin lamellae in grains of feldspar, and of cleavage laminae in micas.

(c) Development of secondary twinning in microcline and possibly in plagioclase.

(d) Recrystallisation of large grains of quartz or sometimes feldspar, as a mosaic of small grains with sutured margins.

(e) Development of small shear-planes, along which secondary quartz, calcite, or even epidote may be deposited.

(f) In rare cases the formation of contorted highly foliated schists (e.g., No. 1334) from non-foliated rocks such as hornfelses.

(g) Possibly the development of strain-slip cleavage in the slates of Haast Pass is to be attributed to this process.

CAUSES OF METAMORPHISM.

In the previous account of the hornfelses and gneisses of the Cascade Valley it was stated (Turner, 1930a, p. 184) that three processes had been concerned in the crystallisation of these rocks as they now exist, the first being the most important. In chronological order these were:—(1) Intense dynamo-thermal metamorphism under meso-zone conditions; (2) invasion and local modification by granite pegmatites, also under meso-zone conditions; (3) retrogressive metamorphism under epi-zone conditions. As a result of evidence obtained during subsequent work, certain modifications, referring especially to the first of the above three processes, are now put forward.

The dominant process has been one of regional progressive metamorphism involving two distinct factors. The first is dynamo-thermal metamorphism in the sense employed by Tyrrell (1930, p. 255), resulting from powerful stress and high temperature controlled by folding movements and depth of burial. As frequently observed in similar instances (e.g., Barrell, 1921), this was aided and modified by a second factor, namely, contact effects resulting from contemporaneous invasion of the folded strata by a subjacent batholith, with accompanying further rise in temperature and permeation of the overlying rocks by volatile magmatic fluids.

The effects of this second phase are especially conspicuous within the zone of oligoclase in the Cascade, Arawata, and Jackson Valleys, in the immediate vicinity of the still unexposed batholith. Here there has been extensive development of hornfelses, hornfelsic paragneisses and hornfelsic mica-schists, the non-foliated or poorly foliated texture of which indicates that high temperature was a much more important factor in their crystallisation than directed pressure. The occasional presence of andalusite has similar significance. In these rocks, too, the presence of porphyroblastic muscovite, occasional minor microcline, and widely disseminated tourmaline and apatite is doubtless to be attributed to the effects of magmatic fluids rising from the subjacent intrusive mass. It has already been pointed out that tourmaline and apatite are also very widely distributed through the schists of the biotite and chlorite zones, many miles beyond the limits of the area where hornfelsing has taken place. Even in the least metamorphosed rocks of the zone of chlorite—the Haast Pass slates—relatively large idioblastic crystals of tourmaline are constantly present, and bear witness to the far-reaching influence of magmatic fluids rising from the depths.

The question now arises as to whether the distribution of the zones of progressive metamorphism in South Westland was governed by dynamo-thermal conditions dependent upon folding, or by the "contact" influence of the subjacent batholith, or by a combination of these factors.

If the progressive metamorphism of the schists of South Westland were entirely a dynamo-thermal process dependent upon folding and depth of burial, some degree of parallelism between the isograds and the strike of the rocks may reasonably be expected. Actually the isograds cut obliquely across the strike, and, as far as can be gathered from the evidence at present available, their courses are probably highly irregular. Of special significance in this connection is the small isolated area of oligoclase-bearing schists in the vicinity of Douglas Creek, Haast Valley. Though the oligoclase isograd crosses the Haast Valley some eight miles west of this area, and a broad belt of schists lying within the biotite zone intervenes, the rocks of Douglas Creek certainly lie within the zone of oligoclase. It is obvious, therefore, that the distribution of the zones has been considerably influenced by the distribution of subjacent magma. On this assumption the quartz-oligoclase-biotite-schists of Douglas Creek, which, as already noted, are unusually rich in tourmaline and apatite, owe their high metamorphic grade to the existence in this vicinity of an upward-projecting cupola of granite, at no great depth below the surface.

The distribution of hornfelsic rocks is also of considerable significance, since their presence in any locality may be taken to indicate proximity to the granite contact. As would be expected, the hornfelses are strictly confined to within the zone of oligoclase. In the Arawata, Jackson, and Cascade Valleys hornfelses, hornfelsic paragneisses, and hornfelsic mica-schists are developed consistently throughout the whole of the oligoclase zone. In the Haast Valley on the other hand, relatively well foliated quartz-oligoclase-biotite-schists are characteristic of most of the zone of oligoclase; the foliation becomes indistinct only when the composition of the feldspar is relatively calcic (oligoclase-andesine), while true hornfelses are never developed even where the metamorphic grade attains its maximum value. There is thus no approach to parallelism between the outer boundary of the hornfelsed "zone" and the oligoclase isograd, such as might be expected if uprise of a granite batholith alone were responsible for the progressive metamorphism of the area. In the south the subjacent intrusion has evidently approached more closely the biotite-oligoclase boundary surface than in the vicinity of the Haast Valley further north.

The conclusion is therefore put forward that the distribution of the metamorphic zones of the Haast-Cascade area was governed by dynamo-thermal metamorphism combined with contemporaneous invasion in depth by an extensive subjacent batholith of granite. This conclusion is supported by the hypothesis advanced by Finlayson (1908a, p. 120) and later adopted by Professor Park (1921), that the schists of Central Otago are arched over a subjacent granite batholith, with which the auriferous and scheelite-bearing veins of this district are genetically connected.

The second process involved in the metamorphism of the South Westland schists and hornfelses, namely, invasion and modification of the more deep-seated of these rocks by veins of pegmatite, has already been discussed fully in a previous section. It was then shown that while this phase definitely post-dated the hornfelsing, it nevertheless occurred while the invaded rocks were still subjected to meso-zone conditions. It should here be noted that the mineralogical changes resulting from pegmatitic injection are not always distinguishable in a particular instance from the more widespread effects of the initial uprise of magma.

The third process was minor retrogressive metamorphism, the effects of which have been summarised in the previous section. In her recent summary of the phenomena of retrogressive metamorphism, Eleanora Knopf (1931, pp. 6, 7) emphasises the fact that when a mineral assemblage in mutual equilibrium under high pressure-temperature conditions is subjected to conditions of decreasing temperature and pressure, there is normally a very marked lag in adjustment to the new conditions. Consequently katagneisses are frequently exposed at the earth's surface by denudation, without any attempt at readjustment of the mineral assemblage to an association in mutual equilibrium at ordinary temperatures and pressures. Diaphthoresis or retrogressive metamorphism occurs only when the rocks in question have suffered deformation involving strong differential movement of the constituent parts. This acts as a trigger force, and instigates readjustment to the new conditions. The rocks of the Haast-Cascade area which show the effects of diaphthoresis must then have been subjected to fairly severe deformation under epi-zone conditions. The resultant shearing was especially intense in the vicinity of the Cascade-Jackson Valley Fault which presumably first came into existence about this time. There is no petrological evidence to show whether this second deformation was simply a late phase of the main orogenic movement responsible for the original metamorphism, or an independent event occurring at a subsequent period in the history of the area. This question will be discussed later.

To summarise the position, it may be stated in conclusion that three phases are involved in the metamorphism of the rocks of South Westland:—

(1) Progressive regional metamorphism resulting from the combined effects of dynamo-thermal metamorphism due to folding, and "contact" metamorphism on a large scale following upon invasion of the lower levels by a subjacent batholith.

(2) Invasion of the lower zones by granite pegmatites and local development of composite gneisses under meso-zone conditions.

(3) Later deformation and resultant retrogressive metamorphism under epi-zone conditions.

DATE OF METAMORPHISM.

In the previous paper referred to (Turner, 1930a, pp. 185, 186) the quartz-albite-chlorite-schists of the Olivine Range were correlated with the Maniototo Series of Central Otago, and provisionally separated from the more intensely metamorphosed gneisses and hornfelses of the coastal belt, which were grouped as an Older Metamorphic Series believed to antedate the Maniototo Schists.

Subsequent field work has shown, however, that in the Haast Valley there is perfect gradation, as a result of progressive metamorphism, from quartz-albite-chlorite-schists of the Central Otago type, through quartz-plagioclase-biotite-schists, to oligoclase-biotite-gneisses similar to the most metamorphosed members of the " Older Metamorphic Series " of the Cascade Valley. In the Cascade, Jackson, and Arawata Valleys this transition is completely masked by the fact that the Cascade-Jackson Valley Fault has brought into juxtaposition rocks of widely different metamorphic grade.

It is therefore not possible to separate the schists of southern Westland from the Maniototo Series of Central Otago, and the term Older Metamorphic Series as applied to the Cascade Valley rocks must lapse. It is, of course, possible that the South Westland schists are stratigraphically either older or younger than those of Central Otago, while the latter may themselves include strata of different ages. At present all that can be stated is that the schists of Central Otago and those of the Haast-Cascade area owe their present condition to contemporaneous progressive metamorphism.

Judging from the observations of Haast (1879) and Cox (1877a), the belt of highly metamorphosed schists, which extends along the western flank of the main alpine chain north of the area under consideration, is probably continuous with the area of schists and gneisses south of the Haast River. These northern schists have been mapped and examined at various points between Hokitika and north-west Nelson, and are classed as the Arahura or Aorere Series in the various Geological Survey Bulletins dealing with this region. It appears extremely probable that the schists of northern Westland and Nelson, the Maniototo schists of Central Otago, and the rocks described in this paper from South Westland were all metamorphosed contemporaneously during a single period of regional progressive metamorphism.

The date of this metamorphic period is still uncertain, but a certain amount of evidence bearing on the problem has gradually accumulated, and may conveniently be examined at this stage. Some of the more significant points may be summarised as follows:—

(1) The schists of Central Otago " are flanked to the north-east and south-west by a semi-schistose series of greywackes and argillites into which they merge apparently imperceptibly. These are in turn succeeded without obvious break by the Permian (?) fossiliferous sediments at Clinton in the south and the late Middle Triassic beds at Mount St. Mary, near Kurow, in the north " (Benson, 1928, p. 56).

(2) In North Westland and Nelson there is apparently no break between the argillites and greywackes of the main divide and the highly metamorphosed rocks of the Arahura Series further west (e.g., Morgan, 1908, p. 77). In the Haast-Cascade area there is also perfect transition from slates in the vicinity of Haast Pass, through schists of intermediate grade, to the highly metamorphosed gneisses and schists of the coastal belt.

(3) It has been demonstrated by Marshall (1917) that in the Tuapeka district there is perfect transition, by progressive metamorphism, from unaltered greywackes to the schists of Central Otago.

(4) Triassic and Jurassic conglomerates in many localities throughout New Zealand contain very plentiful boulders of granite and other plutonic rocks.

(5) In the Parapara district of Nelson, Bell, Webb, and Clarke (1907, p. 46) record the presence of boulders of schist in conglomerates of the Haupiri Series, which are usually correlated with the Te Anau Series of Permo-Carboniferous age (e.g., Benson, 1921, p. 17). A pebble of tourmaline-schist was also collected by the present writer from a large boulder of Te Anau breccia in the Routeburn Valley (north-west of Lake Wakatipu).

(6) Professor J. Park has informed the writer that he has observed boulders of mica-schist in the Triassic conglomerates of Nelson.

From consideration of items 1, 2, and 3 above, it would appear, on the assumption that no break of major importance separates the schists from the fossiliferous Permian and Triassic beds, and in view of the substantial continuity of the Triassic-Jurassic sequence in New Zealand, that the metamorphism must have occurred in Lower Cretaceous times and coincided with the post-Hokonui orogeny. Writing in support of this hypothesis, Professor Benson (1921, p. 28) has stated that " this also would afford an explanation of the absence of pebbles of the schist, or quartz-pebbles derived from the schists, and of micaceous sands, from the Mesozoic semiglomerates and greywackes adjacent to the areas of schist."

On the other hand it is equally evident from items 4, 5, and 6 above, that during Triassic and Jurassic times, and apparently even as early as the middle or later Palaeozoic, an extensive area of strongly metamorphosed rock invaded by granites was already exposed by denudation. Whether the boulders of these Palaeozoic and Mesozoic conglomerates were worn from schists and granites of the same age as those now so extensively developed in Nelson, Westland, and Otago, it is impossible to state. They, nevertheless, constitute undoubted evidence of ancient metamorphism.

Two alternative hypotheses, neither of which can be regarded as proved beyond doubt, therefore present themselves:—

(1) That two periods of intense metamorphism and granite intrusion must be recognised—an early period affecting rocks now represented in Palaeozoic and Mesozoic conglomerates, and a later period (Lower Cretaceous) responsible for the metamorphism of the schists of Central Otago, Westland, and Nelson.

(2) That there was a single, very ancient period of intense metamorphism, at least as remote as Palaeozoic. The writer favours this second hypothesis, though it necessitates the existence of an as yet undiscovered major break between the Central Otago schists and the overlying Triassic and Permian sediments. In a

later section, when the tectonic significance and age of the great peridotite intrusion has been discussed, further evidence in support of this view will be brought forward.

It will also be shown later that the subsequent epi-zone deformation, which brought about partial retrogressive metamorphism of the schists and hornfelses of the Cascade Valley, also considerably affected the peridotites and associated intrusive rocks, the age of which is probably Lower Cretaceous. If the writer's view as to the date of the main metamorphism is correct, the movements giving rise to retrogressive metamorphism must therefore belong to a much later period of orogeny than that during which the main progressive metamorphism was brought about. It is highly probable that both the diaphthoresis of the schists and dynamic metamorphism of the peridotites are to be attributed to the Lower Cretaceous orogeny, which so profoundly affected the New Zealand region.

IGNEOUS ROCKS INTRUSIVE INTO THE METAMORPHIC SERIES.

Pegmatites.

Dykes and veins of pegmatite, ranging from one inch to two or three feet in width, invade the rocks of the oligoclase zone in the Cascade, Jackson, and Arawata Valleys, where they are often extremely abundant. In the Haast Valley, pegmatites are absent from all but the most highly metamorphosed of the gneisses of the oligoclase zone, which they invade on a minor scale about 1 mile south of Mr J. Cron's homestead.

These rocks have already been described in the previous paper dealing with this area (Turner, 1930a, pp. 181, 182). There is little to add to the previous descriptions except a brief statement with reference to the composition of the plagioclases. Detailed examination of their optical properties* has shown them in some cases to be slightly more calcic than previously stated. The actual redetermined values now given are:—

No. 1219 (1 ml. S.W. of Martyr Br.)—between $Ab_{85}An_{15}$ and $Ab_{80}An_{20}$
No. 1220 (S. end Martyr Br.)—$Ab_{90}An_{10}$
No. 1221 (S. end Martyr Br.)—$Ab_{67}An_{33}$
No. 1222 (Gorge of Creek on N. side of Martyr Ford)—$Ab_{83}An_{17}$
No. 1356 (Gorge of Creek on N. side of Martyr Ford)—$Ab_{90}An_{10}$

It is frequently asserted that the abundant pegmatite veins, which often are associated with highly metamorphosed schists in other parts of the world, are not of magmatic origin, but are "a product of metamorphism, and have been derived from the sediments which they traverse " (Bailey, 1923, p. 322). There can be no doubt, however, that the pegmatites of the Haast-Cascade area represent the crystallisation-products of volatile magmatic extracts rising from the subjacent granite batholith, the presence of which has already been inferred from other evidence. Not only have the pegmatites of this area had an obvious and often profound " contact " influence upon the invaded hornfelses, but their composition, especially their high content of potash feldspar definitely precludes any possibility of derivation from the adjacent metamorphic rocks.

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* Comparison of principal refractive indices where possible with those of quartz and Canada balsam; determination of optic sign and approximate estimation of optic axial angle; determination of maxium extinction angle with reference to albite twinning plane in sections perpendicular to 010; and of extinction angles X to 001 cleavage and Z to 001 cleavage in sections perpendicular to Z and X respectively.

As previously stated, the pegmatite injection occurred shortly after the period of hornfelsing, but while conditions of maximum metamorphism still prevailed. They certainly antedate the final period of retrogressive metamorphism, when they suffered very severe crushing often accompanied by chloritisation of biotite and partial sericitisation of plagioclase. Cataclastic effects of this nature are especially well shown by a tourmaline-pegmatite (No. 1356), recently collected from the gorge of the small creek, which drains into Martyr Creek just below the ford across the latter stream. In this rock crystals of quartz, albite-oligoclase and tourmaline originally 5 mm. in diameter have frequently been reduced to a completely crushed and partially recrystallised mosaic of tiny granules, through which larger angular fragments are scattered irregularly.

PERIDOTITES AND ASSOCIATED ROCKS.

The Material Studied: An account of the peridotites and associated dyke-rocks which are extensively developed along the western flank of the Olivine Range, from the Jackson Valley to Red Mountain, some 25 miles south-west (see map), has already been published (Turner, 1930a, pp. 186-199), and will not be unnecessarily recapitulated in the present paper. To this, however, are now added descriptions of further material collected on the 1930 expedition, and of certain additional specimens from the vicinity of Red Mountain, collected by Dr G. Moir, and presented by him to the Geology Department of the Otago University. The following observations are therefore intended to supplement the account already recorded, and to modify those of the original conclusions and descriptions which have been found as a result of further work to be incorrect or incomplete.

The rocks of the South Westland peridotite belt include a considerable variety of types, which may be grouped for convenience of description into eight classes, of which the first is by far the most extensively developed:—

(1) Peridotites and altered derivatives.
(2) Pyroxenites and altered derivatives.
(3) Chromite rocks.
(4) Hornblendites and related rocks.
(5) Altered " Gabbros."
(6) Nephrites.
(7) Veins of hydrothermal origin.
(8) Epidote-hornfelses developed by contact metamorphism of the invaded schists and hornfelses.

Peridotites and Altered Derivatives: A number of additional specimens were collected from the large morainic boulders which mantle the surface of the Cascade Plateau, and from the boulders in the bed of Laschelles Creek derived directly from the Plateau moraines. Since this material represents detritus brought down from almost the full extent of the peridotite belt, examination of it throws valuable light upon the nature of the peridotites beyond the limits of the area mapped.

The most abundant rock type from this locality is harzburgitic dunite. (Nos. 1239, 1240, and 1241 previously described; Nos. 1378, 1381, 1382, 1383), consisting mainly of olivine with from 3% to 10% of fairly coarsely crystalline allotriomorphic enstatite. There are always minor but constant amounts of deep brown chromite, or less commonly yellowish brown picotite (No. 1378). With increasing enstatite the dunites pass into true harzburgites, such as No. 1380, which, in addition to plentiful scattered crystals of enstatite, contains large clots of this mineral, as much as 3 cm. in diameter, easily distinguishable in hand-specimen. The olivine of this specimen shows only incipient alteration to antigorite, but minor patches of very fine antigorite and talc have already developed along the cleavage planes of the pyroxene. Chromite is not abundant. No. 1396 is a lherzolitic dunite containing both augite and enstatite, each to the extent of about 5%, while No. 1384 is a true lherzolite, the composition of which is olivine 70%, enstatite 10%, clear monoclinic pyroxene 20%, and accessory chromite. Though all the peridotites from this locality show the effects of intense shattering, they are consistently free from alteration which has never advanced beyond the incipient stage.

Supplementary material from various points on Red Spur and Martyr Spur confirms the conclusion formerly reached, that the rocks of the northern end of the peridotite belt are mainly partially serpentinised wehrlites and wehrlitic dunites, in which the olivine shows all stages of replacement by antigorite, while augite typically is altered to a semiopaque brownish substance which appears to have a moderately high birefringence. No. 1400 (Red Spur) is a type hitherto unrecorded, however. It is a deep green semitranslucent serpentine obtained from one of the major shatter planes, which both here and elsewhere were frequently observed to be lined with similar material. The original rock must have been a much crushed wehrlitic dunite containing about 5% of augite. About one-half of the olivine has been converted to chrysotile serpentine (optically + with small axial angle), which now builds up clear patches several millimeters in width, showing perfect mesh structure, while the augite is either clear and unaltered, or partially replaced by pseudomorphous bastite. The serpentinisation of the rock has thus proceeded along lines totally different from those normally followed in the peridotites of this area, and doubtless was effected by passage of magmatic waters along the major crush planes, after shearing had ceased. Veinlets of chrysotile asbestos of similar origin commonly occupy fractures of this type along the full extent of the peridotite belt.

Specimens collected by Dr Moir from the Red Mountain area include, in addition to previously described types, a dark grey opaque serpentine (No. 1413, margin of Red Mt. intrusive mass), which is seen in thin section to consist almost entirely of fine-grained antigorite with perfectly developed " thorn structure " (compare Bonney and Raisin, 1905, p. 702; Pl. XLV, Fig. 3). There are scattered small grains of secondary magnetite, and several crystals of bastite partly or almost completely converted into antigorite (compare Benson, 1914, pp. 674, 675; Turner, 1930a, p. 190), and presumably pseudomorphous after original enstatite. From analogy with previously described specimens, the rock may probably be classed as an antigorite-serpentine derived from original harzburgite.

A serpentine hitherto unrecorded from this area is No. 1385 collected from a single boulder in the bed of Martyr Creek, at the ford where the track crosses this stream. It is a homogeneous, fine-grained black serpentine, which is seen in section to consist of almost totally isotropic serpentine, charged with abundant small granules of secondary iron-ore. With intense convergent illumination some of the serpentine was observed to be very feebly birefringent, giving anomolous blue interference tints between crossed nicols, and showed rather imperfect " thorn structure."

With reference to hydrothermal alteration of the peridotites of the Olivine Range, examination of new material has merely confirmed the conclusions originally reached (Turner, 1930a, p. 197).

Pyroxenites and Altered Derivatives: The pyroxenites occur as clear-cut veins and dykes, often only a few inches, but sometimes several feet in width, which invade the peridotites and serpentines of the Olivine Range. Along the peridotite belt itself the relation of pyroxenite to peridotite is usually obscured by the fact that the rocks of the outcrop are intensely shattered by frost action, but the sharply defined boundaries of the veins and their undoubtedly intrusive nature may clearly be observed in some of the larger boulders of peridotite (frequently five or six feet wide) which mantle the Cascade Plateau.

Relatively unaltered pyroxenites so far recorded (Turner, 1930a, p. 191) include an enstatite-pyroxenite (No. 1246) with minor augite and olivine from the Cascade Plateau boulders, a somewhat similar rock from Red Mountain (No 1247) containing about 25% of augite and a little green chrome-diopside, and an augite-pyroxenite (No. 1245) collected from Martyr Spur and containing in addition to monoclinic pyroxene a small amount of enstatite and about 20% of antigorite replacing olivine. To these may be added three additional records: Nos. 1376 and 1377 from veins in morainic boulders of peridotite, Cascade Plateau, and No. 1369 collected from a small dyke invading the wehrlite of Red Spur. No. 1376 is a dark green comparatively fine-grained pyroxenite, the composition of which is monoclinic pyroxene with schiller structure 90%, olivine 8%, and enstatite 2%. The pyroxenes occur in clear, unaltered allotriomorphic crystals about 2 mm. in length, among which the olivine, showing incipient alteration to antigorite is interstitially distributed (Pl. 28a, Fig. 13). No. 1377 is a coarse enstatite-pyroxenite containing small amounts of interstitial olivine and accessory chromite, and resembles No. 1246 from the same locality. No. 1369 is an augite-pyroxenite, consisting almost entirely of coarse schillered augite and small patches of decomposition products possibly representing original olivine.

The pyroxenites of the Olivine Range have in many cases undergone intense hydrothermal alteration, the mineralogical changes observed being considerably more diverse than those involved in serpentinisation of the peridotites of the same region. Seven types of altered pyroxenites may be recognised: antigorite rocks, antigorite-talc rocks, chrysotile rocks, garnetiferous chlorite-antigorite rocks, garnetiferous diopside-chlorite-magnetite rocks, chlorite rocks, and diopside-vesuvianite rocks.

(1) Antigorite rocks. As in the peridotites, enstatite and any olivine which may be present in the pyroxenites normally alter to antigorite with perfect " thorn structure," while monoclinic pyroxene is in this case also commonly affected in a similar way. Rocks which have been conspicuously altered in this manner are Nos. 1375, 1381, 1401, and 1403, in addition to Nos. 1244, 1252, and 1261 already described (Turner, 1930a, pp. 190-194).

No. 1401 (dyke near eastern margin of peridotite intrusion, Martyr Hill, Olivine Range) is a coarse grey augite-pyroxenite consisting of plates of pyroxene sometimes as much as 5 cm. to 6 cm. in length. In section some of these crystals are seen to be relatively fresh, but many have been replaced by a felt of antigorite, throughout which cleavage prisms of residual pyroxene and secondary magnetite are scattered in variable amounts. A few crystals are dusted with the opaque brownish decomposition product so commonly observed coating the aluminous pyroxene of the wehrlites, and enclose long streaks of granular magnetite which has been deposited along the cleavage cracks.

A relatively early stage in alteration is seen in No. 1375 (boulder, Laschelles Cr.), a pale coloured pyroxenite, which in thin section is seen to consist entirely of colourless monoclinic pyroxene and antigorite. The latter mineral builds up clear patches constituting perhaps 25% of the total composition of the rock, and surrounding crystals of pyroxene which fray out terminally into cleavage prisms still in optical continuity with the main crystal, but separated from one another by fine-grained encroaching antigorite. No. 1261 (Red Mountain intrusion) represents a more advanced stage in serpentinisation of an augite-enstatite-pyroxenite, in which both pyroxenes are now rather more than half converted to antigorite and accessory magnetite. No. 1403, from the same locality, is a coarse-grained light green semi-translucent serpentine with flaky fracture, and appears originally to have been an enstatite-pyroxenite with very little augite. Transformation of enstatite to antigorite is almost complete, but residual cleavage prisms, and occasional larger fragments stabbed through with antigorite blades, still persist throughout most of the section.

Apple-green, semi-translucent serpentines, which break with the flaky or splintery fracture characteristic of antigorite rocks, and macroscopically closely resemble nephrite but for slightly inferior hardness (5 to 5½), are represented by two specimens both collected from boulders—No. 1244 (Turner, 1930a, p. 190), and No. 1386 obtained from the bed of Martyr Creek, 1½ miles above its junction with the Cascade River. No. 1386 consists entirely of blades of antigorite 0.1 mm. to 0.2 mm. in length showing most perfect " thorn structure," though there are several somewhat ill-defined patches which appear originally to have been bastite, now almost completely replaced by antigorite. No. 1244 also consists mainly of antigorite, but contains in addition a minor amount of a pale greenish mineral identified as a serpentine between chrysotile and xylotilite, together with occasional crystals of bastite showing partial replacement by antigorite. It is possible that these rocks are derivatives of original peridotites, but it seems more probable that they are actually completely serpentinised pyroxenites.

(2) Antigorite-talc rocks. These are represented by a single specimen, No. 1249, obtained from a dyke in the serpentine of Martyr Spur, about three-quarters of a mile above the bush line (Turner, 1930a, p. 192). Augite and olivine have both been replaced to a large extent by fine-grained antigorite, but enstatite, which was fairly abundant in the original pyroxenite, has been altered either to talc or to a mixture of talc and antigorite. Macroscopically chlorite, magnetite, and garnet are all visible in minor amount, so that the rock differs from the garnetiferous chlorite-antigorite rocks only in the presence of abundant talc.

(3) Chrysotile-serpentines. Pyroxenites which have been altered to chrysotile-serpentines are of rare occurrence and were obtained only from boulders in Martyr Creek, 1½ miles above its junction with the Cascade River. Of these, No. 1253 (Turner, 1930a, p. 194) consists mainly of colourless monoclinic pyroxene now half converted to chrysotile, together with occasional large pseudomorphs of bastite after enstatite. In No. 1389, from the same locality, the pyroxene has been completely destroyed, and the rock now consists of chrysotile and bastite, throughout which well cleaved granular masses of a carbonate mineral, about 1 mm. in diameter, are abundantly dispersed, together with about 1% of secondary magnetite, which seems to be especially concentrated in the carbonate-rich areas.

(4) Garnetiferous chlorite-antigorite rocks. Rocks of this type were obtained from dykes invading the peridotite of Martyr Spur, and are represented by specimens Nos. 1248 and 1250 (Turner, 1930a, pp. 192, 193). They are augite-pyroxenites in which the pyroxene has been replaced by pennine and minor antigorite, while small grains of deep red garnet and larger crystals of magnetite are constantly present in relatively small quantities. In No. 1250 the development of prisms of diopside in addition to the other minerals mentioned marks a transition towards the next group.

(5) Garnetiferous diopside-chlorite-magnetite rock. No. 1366 (small dyke, Red Spur) is an extremely altered rock consisting in hand-specimen of well defined patches of white and green material enclosing abundant irregular masses of bright magnetite, often more than 10 mm. in diameter. The most abundant mineral, apart from magnetite, is diopside, which takes the form of well crystallised slender prisms often over 1 mm. in length, scattered among which are interstitial flakes of a colourless chlorite, which also occurs in coarser crystals building up clear diopside-free areas often 2 mm. in diameter. The chlorite is uniaxial, positive, and poorly birefringent, with strong dispersion, and thus appears to be a colourless variety of pennine. It also occurs as coarse crystals with the characteristic anomolous blue interference tint, enclosed within the large grains of magnetite. Pale yellowish garnet, though not abundant, is consistently present in all three sections examined, in the form of small rounded grains which are especially numerous along sparsely distributed fracture lines. Though there is no trace of residual pyroxene, it is concluded from analogy with the rocks of the previous group that the specimen in question is an extreme type of completely altered augite-pyroxenite. The formation of secondary diopside from augite recalls a similar instance described, in the case of a lherzolite from the Shetland Islands, by Phillips (1927, p. 628), who states in this connection that " the secondary production of pyroxene, rather than amphibole, in an altered serpentine is not common. Merrill (1888, p. 489) has described a case. Here original augite is surrounded more or less completely by a narrow irregular border, projecting in the form of sharp teeth for a considerable distance into the serpentine. The new growth, however, is (in all cases) in optical continuity with the original augite."

(6) Chlorite-rocks. No. 1251 (Red Spur) has already been described as a rock showing transition from monoclinic pyroxene to finely crystalline pennine, which develops as well defined bands along the cleavage cracks. The end-product of this type of alteration is exemplified by specimen No. 1414, a fine-grained green rock from the eastern margin of the Red Mountain peridotite mass, resembling the clear green antigorite-serpentines such as No. 1244, but for its greatly inferior hardness. In section, over 99% of the rock consists of minute plates of colourless or very pale green pennine often showing anomolous blue interference tints, and having a structure closely resembling the " thorn structure " so typical of antigorite rocks. There are several small highly irregular granular aggregates of secondary iron ore and greenish yellow garnet.

(7) Diopside-vesuvianite rock. In the previous paper referred to (Turner, 1930a, pp. 196, 197), the writer described an interesting vein rock from Red Mountain, consisting essentially of colourless diopside and a somewhat inferior amount of pale pink vesuvianite. The pyroxene occurs in crystals ranging between 1 mm. and 2 mm. in length, and appears upon careful examination to be undergoing replacement by the vesuvianite. The only other minerals are scattered flakes of green pennine, and colourless zoisite in narrow well defined veinlets cutting irregularly across one of the sections.

The reactions involved in the alteration of the pyroxenites of this area were previously summed up (Turner, 1930a, p. 198) as follows: " Olivine, if present, is always altered partly or wholly to antigorite. The enstatite is usually altered to the same mineral just as in the normal peridotites, but sometimes it has been replaced by talc, a mixture of talc and antigorite, or rarely by bastite. The augite is frequently converted into pennine, with which grains of garnet and prisms of diopside may be associated. Sometimes it is altered to antigorite, . . . while rarely it may be decomposed to the opaque brownish substance which is so commonly met with in the wehrlites of the main intrusion. In one case conversion of augite to diopside was observed." To the above may be added replacement of monoclinic pyroxene by vesuvianite.

The secondary minerals thus produced by alteration of pyroxenes include antigorite, chlorite, talc, diopside, garnet, magnetite, and vesuvianite. Most of these are typical stress minerals, and shearing stress must therefore have had a profound influence upon the alteration process. The importance of the part played by water is indicated by the prevalence among the reaction products of minerals such as antigorite, chlorite, talc, and vesuvianite whose molecules contain OH groups. It is obvious that in some cases, e.g., during the change from augite to antigorite or to chlorite, the reaction was more than simple hydration, and involved removal of lime in solution, while in other instances, such as the replacement of pyroxene by vesuvianite, lime, and probably alumina must have been added and magnesium removed during the reaction. Similarly the formation of the diopside-chlorite-magnetite rock No. 1366 doubtless involved addition of considerable amounts of iron. Other instances might be quoted.

In conclusion, it may therefore be stated that the alteration of the original pyroxenes was a hydrothermal process which took place under conditions of marked shearing stress, and which frequently involved subtraction or addition of such bases as lime, alumina, magnesia, and iron.

Chromite Rocks: The peridotites of the Cascade Valley and their altered derivatives normally contain chromite in accessory proportions, while in rare instances picotite has been observed in these rocks. In the proxenites, on the other hand, chromite is often completely absent, though occasionally present as sparsely scattered grains of small size. Rocks containing a high percentage of chromite also occur, however, and may be grouped into three classes, viz., chromite-olivine rocks, altered chromite-pyroxene rocks, and chromite-serpentine rocks.

The genesis of these chromite rocks is of some interest in view of recent investigations bearing upon the origin of chromite deposits in general (e.g., Sampson, 1929; Ross, 1929; Fisher, 1929). These writers agree that deposits of chromite have not all originated by segregation of early-formed crystals separating out from a basic magma, but in many cases must be due to crystallisation at a much later stage. Fisher (1929, p. 692) thus recognises three distinct periods of crystallisation of chromite: " (1) Chromite of the early magmatic period is the first mineral to crystallise . . . (2) Chromite of the late magmatic period is later than the ground-mass minerals, and occurs in zones of crushed olivine, in cleavages of the cleavable minerals, and as replacements of the earlier pyrogenic silicates of the groundmass. (3) Chromite of the hydrothermal period is definitely later than the pyrogenic silicates, and is associated with deuteric minerals; the chromite of this period was formed by early or late hydrothermal solutions.''

Chromite-olivine rocks or chromite-rich dunites occur *in situ* about a quarter of a mile south-west of the crest of Martyr Hill, not far from the eastern boundary of the peridotite belt, in the bed of the tributary creek which drains the southern slope of Martyr Hill, and falls into the gorge of Woodhen Creek. No. 1235 is a typical specimen, consisting of olivine which has undergone incipient alteration to antigorite, and chromite which makes up about 30% of the total composition. The latter mineral is concentrated in parallel bands from 1 mm. to 3 mm. in thickness, interspersed with olivine-rich bands of somewhat greater width. It occurs in unfractured noticeably rounded grains varying between 0.5 mm. and 1 mm. in diameter, which are surrounded by and enclosed in olivine. There is perfect transition from normal dunite to chromite-olivine rock, the extent of which is thus ill-defined and quite limited. From the field occurrence alone it is obvious that the chromite rocks of this type owe their existence to accumulation of early-formed crystals of chromite, a conclusion that is borne out by the relation of olivine to chromite as seen in thin section, and by the rounded form and unfractured nature of the individual chromite crystals, both of which are regarded by Fisher (1929, pp. 711, 719) as criteria of the " early magmatic period " of crystallisation.

Dark coloured rocks consisting of chromite and altered pyroxene (e.g., Nos. 1361, 1373) occur at several points along the crest of Martyr Spur about half a mile above the bush line. Their relation to the enclosing peridotite could not be observed, since masses of broken talus resulting from frost action conceal the outcrop. The hand-specimen consists of coarsely granular chromite set in a soft apple-green serpentinous matrix. In section the most abundant mineral is chromite, which occurs as idiomorphic or subidiomorphic crystals between 0.2 mm. and 0.5 mm. in diameter, usually aggregated into composite unfractured masses ranging from 2 mm. to 3 mm. in width. In section No. 1361 the chromite individuals are enclosed in or enwrapped by coarse allotriomorphic crystals of monoclinic pyroxene, which is sometimes almost unaltered, but usually shows partial or complete replacement by a fine-grained aggregate of serpentine and zoisite. The serpentinous material is colourless, uniaxial, and positive, with a birefringence between 0.005 and 0.01, and often shows distinct cleavage; its optical properties thus agree well with those of chrysotile, but it lacks the fibrous habit characteristic of that mineral. The zoisite is mainly in minute, almost isotropic, highly refringent, grains, but occasionally the individual crystals reach about 0.2 mm. in diameter, in which case the mineral is seen to be definitely biaxial and positive, with a small optic axial angle, while the dispersion is sufficiently marked to produce greenish yellow anomolous interference tints. Alteration of the pyroxene is always especially conspicuous in the immediate vicinity of the chromite grains, which are often separated from relatively unaltered pyroxene by a narrow fringe of zoisite and serpentine. Many of the grains of chromite are partially bordered by irregularly developed rims of a clear, deep yellowish green isotropic mineral with only moderately high refractive index. The only minerals with similar properties listed by Winchell (1929, p. 106) are garnierite and the rare hydrated nickel carbonate zaratite, both of which may occur associated with chromite and serpentine. Secondary veinlets 0.1 mm. to 0.2 mm. wide, consisting of relatively coarse serpentine optically similar to that developed throughout the matrix of the rock, are fairly common. In No. 1373 some of the secondary veinlets consist largely of a clear colourless mineral the exact nature of which is uncertain. The refractive index is high and the double refraction weak; the interference figure is biaxial and negative, the optic axial angle being definitely small; there appears to be no cleavage. The negative optic sign and lack of cleavage distinguish the mineral from zoisite and clinozoisite. It appears most probably to be vesuvianite, for though it is definitely biaxial Winchell (1927, p. 344) states that in some cases vesuvianite may have an optic axial angle ranging from 30° to 60°.

Though the chromite-pyroxene rocks have been profoundly affected by hydrothermal solutions, there seems to be no evidence that deposition of chromite was connected with the alteration process. On the contrary, the texture of the less altered portions of the rock is most reasonably explained on the assumption that both the chromite and the enclosing pyroxene are primary magmatic minerals, the former being first to crystallise. It may also be pointed out that the distribution of the chromite bears no relation to the degree of serpentinisation of the pyroxene. The tendency for alteration to be especially pronounced in the immediate vicinity of chromite grains has already been commented upon, and was considered by Fisher (1929, pp. 701, 703) in the case of American rocks to indicate " a genetic relationship between the chromite and the deuteric minerals." It seems more probable, in the present instance at any rate, that this phenomenon may be traced ultimately to local crushing of pyroxene immediately adjacent to grains of chromite during shearing, as a result of differences in mechanical properties of these two minerals.

The evidence available suggests that the chromite-pyroxene rocks and their serpentinised derivatives have originated as dykes invading the peridotite. Both chromite and pyroxene have crystallised from the same magma at a late stage, subsequently to the consolidation of the main peridotite mass.

The chromite-serpentine rocks occur as small dykes or veins invading the peridotite of Martyr Spur (No. 1374) and Red Spur (Nos. 1363, 1368, 1372). In every case the principal constituent is feebly translucent deep reddish brown chromite, in the form of allotriomorphic much shattered grains set in a finely crystalline matrix of serpentine, which also occupies the cracks traversing the chromite grains. Whenever the serpentine is sufficiently coarse for its optical properties to be determined, it is found to be uniaxial, positive, and poorly birefringent. Section No. 1374a shows the sharply defined boundary between the completely serpentinised material of a chromite-serpentine vein, and the invaded rock—in this case a partially serpentinised dunite (Pl. 28a, Fig. 14).

In many respects the chromite-serpentine rocks of the Olivine Range resemble closely the chromite rocks which Fisher (1929) believes to be of hydrothermal origin. Nevertheless they are distinguished from the completely serpentinised phase of the chromite-pyroxene rocks only by absence of zoisite and the allotriomorphic form and shattered state of the chromite itself. The writer therefore suggests that they are probably the completely altered equivalents of rocks consisting originally of pyroxene and chromite. That serpentinisation took place subsequently to crystallisation of the chromite is clearly indicated by the presence of serpentine matrix occupying cracks in the chromite grains.

Hornblendites and Related Rocks: Small dykes and veins of fine-grained dark coloured rocks, in which primary magmatic hornblende is the dominant constituent, invade the rocks of the peridotite belt at several points in the vicinity of Red Mountain, from which locality a number of specimens have been collected by Dr Moir. Similar rocks were obtained by the writer from a small dyke on the crest of Martyr Spur, and from a boulder in the bed of Martyr Creek. In some cases hornblende was apparently the only primary constituent, but many of the rocks originally contained a considerable amount of plagioclase, now represented by zoisite or albite. Augite is sometimes present in small quantities. The following descriptions illustrate the characteristics of this group of rocks:—

No. 1415 (near eastern margin of peridotite intrusion, Red Mountain). The original constituents of the rock were strongly pleochroic reddish brown hornblende and a somewhat less amount of plagioclase. The hornblende occurs in allotriomorphic or subidiomorphic crystals about 1 mm. in length, now largely bleached to a pale amphibole feebly pleochroic from pale yellowish (X) to pale green (Z). The feldspar was originally idiomorphic, but is now completely replaced by opaque, white granular saussurite, in which the Prussian blue interference tint of zoisite may occasionally be distinguished, while minute grains of clear albite occur interstitially among the saussurite pseudomorphs and hornblende crystals. The bleached hornblendes sometimes enclose secondary sphene, while iron ore occurs as a minor accessory.

No. 1259 (dyke, Red Mountain) is a more intensely altered rock, the original composition of which must have been close to that of the previously described specimen. The hornblende is pinkish brown, and occurs in ragged, often bent and twisted prismatic crystals which fray out terminally into tufts and sheaves of tremolite needles. Colourless transparent zoisite, accompanied by minor interstitial albite and quartz, have entirely replaced the original feldspar, the crystal form of which has also been completely destroyed.

Nos. 1258 and 1408 (dykes, Red Mountain) are hornblende-zoisite rocks with small amounts of interstitial quartz and albite. The hornblende is a much paler variety than in the previous specimens, the pleochroic scheme being:—

X = very pale yellow
Y = pale yellowish green
Z = pale brownish green
$X < Y < Z$

It is sometimes partially bleached to a colourless amphibole in optical continuity with the normal green hornblende. The zoisite is clear, colourless, biaxial, and positive, and shows the usual Prussian blue tint between crossed nicols. Though much of the zoisite doubtless represents original plagioclase, in some parts of the section it appears definitely to be replacing hornblende.

No. 1410 was collected from a hornblendite dyke which cuts a zoisite-albite rock (No. 1411) close to the eastern margin of the peridotite mass near Red Mountain. The rock consists mainly of pale greenish hornblende, which has suffered partial alteration to coarsely crystalline serpentine in some parts of the section. The serpentine is a nearly uniaxial, positive variety close to chrysotile. Interstitial rounded masses of granular zoisite from 0.5 mm. to 1 mm. in diameter are scattered throughout the section, and appear to represent original feldspar.

No. 1412 (Red Mountain). About 60% to 70% of the rock is pale green hornblende, which usually either frays out terminally into colourless amphibole or contains a central bleached zone of similar material. The hornblende crystals are enclosed in a matrix of finely crystalline shapeless grains of untwinned albite (Pl. 28a, Fig. 15). Zoisite with the usual Prussian blue anomolous interference tint is by no means abundant, and its development is confined to the immediate vicinity of hornblende crystals. Distinctly pleochroic pink sphene occurs as an accessory.

No. 1402 (dyke, Martyr Spur, Olivine Range). Strongly pleochroic deep reddish brown to pale pinkish hornblende, now largely bleached, or frayed out into pale green actinolite needles, makes up about 60% of the rock. It is set in a matrix the chief constituent of which is colourless isotropic serpentine, containing abundant inclusions of pale green actinolite and colourless granular garnet, as well as scattered irregular masses of sphene ranging from 0.1 mm. to 1 mm. in diameter. The latter mineral exhibits strong pleochroism from colourless to deep pink. Epidote and zoisite are present only as accessory grains of small size. There are also several allotriomorphic crystals of almost unaltered augite, which are sometimes enclosed in hornblende, but may also occur free in the serpentine matrix.

No. 1390 (boulder, ford across Martyr Creek, 1½ miles above Cascade junction). This is a relatively coarse-grained rock of rather striking appearance, in which dark crystals of hornblende are set in a green altered matrix. The principal constituent is hornblende in coarse crystals ranging from 1 mm. to 3 mm. in diameter, which are strongly pleochroic according to the following scheme:—

X = pale pink
Y = deep reddish brown
Z = slightly deeper reddish brown
$X < Y < Z$

The larger crystals sometimes enclose small rounded cores of colourless augite. The brown amphibole is frequently bordered with an optically continuous fringe of green hornblende which is pleochroic from fairly deep bluish green (Y and Z) to very pale yellow (X). The large hornblendes are enclosed for the most part in a mass of unoriented diopside prisms and fibrous remnants of green hornblende, throughout which occur small patches consisting of coarsely crystalline pennine or coarse allotriomorphic pink garnet. The chlorite is a pale variety of pennine, uniaxial, positive, and poorly birefringent, giving anomolous yellowish brown interference tints between crossed nicols. The pleochroic scheme is

X = Y = pale bluish green
Z = very pale yellow
$X = Y > Z$

Undoubted examples of transition from green hornblende to chlorite or a mixture of chlorite and diopside, and from both varieties of hornblende to diopside have all been observed in this section. In one or two places colourless transparent zoisite also appears to be replacing green hornblende. The mode of origin of the garnet is not clear. It occurs in large masses ranging up to 3 mm. in diameter, which sometimes contain small but conspicuous interstitial crystals of a mineral, the properties of which agree exactly with those of bowlingite. It is strongly pleochroic from pale golden yellow (X) to deep brownish yellow ($Y = Z$). The birefringence is relatively high, and there is a single well-marked cleavage perpendicular to X. The only primary minerals in the rock are brown hornblende and augite—the latter in very small quantity—and the rock is therefore classed as a much altered hornblendite.

In a previously published description of a hornblende-zoisite rock (No. 1258) from Red Mountain (Turner, 1930a, p. 196) the suggestion was made that the rock probably represented a completely recrystallised gabbroid dyke, in which augite had been converted to green hornblende, and labradorite to zoisite and albite. Examination of many additional sections of related rocks nevertheless has failed to yield any evidence of secondary origin for the hornblende. On the contrary, when augite is present, its relation to the enclosing hornblende indicates clearly that the latter is also a primary mineral, which has crystallised directly from a basic magma, as a result of reaction, according to Bowen's well-established principle, between earlier formed crystals of augite and the melt itself. The hornblendic dyke-rocks thus consisted originally of hornblende, variable amounts of plagioclase, and sometimes a little augite.

The observed mineralogical transformations involved in the alteration of these rocks after their consolidation may be summarised briefly as follows:—

(1) Brown hornblende ——> green hornblende.

(2) Hornblende ——> tremolite or actinolite.

(3) Hornblende ——> serpentine.

(4) Hornblende ——> chlorite.

(5) Hornblende ——> zoisite.

(6) Hornblende ——> diopside.

(7) calcic plagioclase ——> zoisite + minor albite and quartz.

(8) calcic plagioclase ——> albite + minor zoisite.

As in the altered pyroxenites, the reaction products are mostly stress minerals, and in many of them, e.g., zoisite, serpentine, chlorite, and according to modern authorities (Warren, 1929; Kunitz, 1930: Posnjak and Bowen, 1931) tremolite, OH groups enter conspicuously into the composition of the molecule. Here, too, then alteration has been brought about by aqueous solutions acting under conditions of stress. It is obvious, however, that during the alteration of hornblende as outlined above, certain bases, especially lime, have sometimes been added, and in other cases have been removed in solution. Similarly while replacement of calcic plagioclase by zoisite implies addition of some lime and removal of soda, this process must have been exactly reversed during the replacement of calcic plagioclase by albite observed in specimen No. 1412.

In addition to the products of the mineralogical changes described above, there are other secondary minerals such as the garnet of Nos. 1390 and 1402, and the serpentine of specimen No. 1402, the exact mode of origin of which is not yet clear.

Altered " Gabbros ": Under this heading are included certain intensely altered white or blotched green and white rocks, which, whenever observed *in situ*, occur as dykes and veins invading the peridotite mass. Except in rare instances the primary minerals have been completely destroyed, and the rocks are now made up of a fine-grained aggregate of secondary minerals, among which one of the calcium aluminium silicates epidote, zoisite, or garnet always predominates. Three main types may be recognised, viz., epidote rocks, zoisite rocks, and garnet-zoisite rocks.

Epidote rocks of this group are known from two specimens (Nos. 1257 and 1388) collected from boulders in the bed of Martyr Creek, 1½ miles above its junction with the Cascade River. Macroscopically they are white or pale grey homogeneous, very fine-grained rocks, which break with a splintery or flaky fracture, recalling that of antigorite-serpentines. About 70% of the rock consists of very small grains of yellow epidote, which is only determinable as such under high magnification. In specimen No. 1388 there are also scattered large, irregular grains of deep yellow highly birefringent epidote, evidently rich in iron. Minute granules of albite occur interstitially among the epidote grains. Highly irregular lenses and streaks consisting entirely of albite and quartz make up the remaining 30% of the section in each of the specimens examined. In section No. 1257 several minute crystals of brown hornblende and a little zoisite were noted, while in No. 1388 very small pale green laminae and fibres of chlorite are constantly present in the epidote-rich areas. This latter section is crossed by a veinlet 1 mm. in width consisting mainly of relatively coarse, intensely strained quartz enclosing idiomorphic crystals of albite. Vermicular colourless chlorite is plentifully developed along one side of this veinlet.

The zoisite rocks are massive white or blotched greenish rocks represented by specimens Nos. 1256 and 1387 obtained from boulders in the bed of Martyr Creek, No. 1294 from boulders alongside the track one mile north of Martyr Bridge, and Nos. 1406, 1409, and 1411 collected *in situ* by Dr Moir from veins invading the peridotite mass of Red Mountain east of Awarua Bay. They are marked by the universal abundance of zoisite, which is typically accompanied by notable amounts of both tremolite and antigorite.

No. 1406 contains conspicuous crystals of residual colourless augite, always enclosed in patches of felted antigorite. The bulk of the rock consists of very small stumpy prisms and granules of zoisite, with a little interstitial antigorite, and possibly a very small amount of albite. The zoisite in this section is elongated parallel to X, and has a relatively high birefringence of about 0.01, these properties indicating a comparatively high iron content unusual in this mineral (compare Winchell, 1927, pp. 353, 354).

Specimen No. 1387 consists of aggregated prisms of zoisite and tremolite with interstitial antigorite, and irregularly developed intervening patches composed entirely of felted plates of this latter mineral. Most of the tremolite is colourless, and is distinguishable from the zoisite by its lower refractive index, but two crystals of pale brown faintly pleochroic amphibole were also noted. The zoisite occurs mainly in small slender prisms with straight extinction and a single vertical cleavage, but there are also clusters of coarser crystals, sometimes over 1 mm. in length, having similar optical properties. The optic axial angle is small, the sign positive, the elongation is positive, and the birefringence is again relatively high—about 0.01 to 0.012—indicating the presence of appreciable Fe_2O_3 in the molecule.

No. 1409 is a coarsely blotched green and white rock in which tremolite is particularly well crystallised as prisms over 1 mm. in length, which, together with minor interstitial antigorite and albite, build up colourless patches of considerable extent, which contrast conspicuously with the pale yellowish areas of granular zoisite. The zoisite is mainly in the form of small idiomorphic prisms with negative elongation, fairly low birefringence, and strong dispersion, but there are also coarser less perfectly shaped crystals with positive elongation, the optic axial angle being small and the optic sign positive. No. 1394 is unusual in that, in addition to coarser tremolite and zoisite which are the main constituents, there are minor quantities of prismatic diopside, conspicuous on account of its high refractive index, medium birefringence, and strongly oblique extinction. There are also areas built up of felted laths of a colourless serpentine with negative elongation.

No. 1256, previously described (Turner, 1930a, p. 195) as a tremolite-antigorite rock, has since been found to contain in addition a high proportion of prismatic zoisite, which was previously confused with the tremolite. It somewhat resembles No. 1387 described above.

Garnet-zoisite rock is known from a single specimen, No. 1254, which was obtained from a dyke of resistant white rock several feet wide, cutting the serpentine of Martyr Spur not far below the bush line. In the previously published description of this rock (Turner, 1930a, p. 194), the zoisite was incorrectly identified as enstatite. The refractive index is too high for enstatite, however, while on careful re-examination interference figures were obtained in several cases, showing the small optic axial characteristic of zoisite. The rock is obviously related to the grossularite-pyroxene rocks of the peridotite belt of Nelson to which Marshall (1911) gave the name rodingite, and which, according to Grange (1927, pp. 162-163), frequently contain zoisite and diopside in addition to garnet.

The recorded occurrences of lime-silicate dyke-rocks intrusive into ultrabasic rocks have been summarised by Benson (1918, pp. 722-723), who has himself traced every gradation from eucrite-gabbros to pure grossularite rocks in the Bingara district of New South Wales (Benson, 1914, pp. 686-688). This supports the original conclusion of Murgoci (1900), that certain of the lime-silicate masses included in the Paringû serpentines of Roumania were altered gabbros. The " rodingites " of the Dun Mountain, Nelson, have also been shown by Benson (1926, p. 43) and Grange (1927) to be due to garnetisation of originally gabbroid rocks, under the influence of " concentrated magmatic water " acting probably at high pressures. Recently Tyrrell (1931, p. 29) has drawn attention to the occurrence in the Ural Mountains of dykes of garnet-pyroxene, garnet-vesuvianite, and garnet-chlorite rocks, which invade serpentinised harzburgites. These rocks have been described fully by Arshinov and Merenkov (1930), who believe that they have originated by " the garnetisation of micro-diorites and the alteration of pyroxenite schlieren by calcium metasilicate solutions liberated in the process of serpentinisation."

The lime-silicate rocks of the peridotite belt of South Westland are believed to have originated in a similar way, by alteration under pressure of basic dyke-rocks, by aqueous solutions rich in lime, rising from the cooling peridotite mass. The alteration was probably effected by the same waters as were responsible for serpentinisation of the rocks of the main intrusion, and their lime content was no doubt derived from monoclinic pyroxenes during this latter process.

The universal abundance of zoisite suggests that the original unaltered rocks must have contained a high percentage of calcic plagioclase. Augite was certainly present in some cases, and may occasionally still persist as residual crystals, which always have undergone partial replacement by antigorite or other serpentine. It is thus reasonable to assume that the clear patches of serpentine which invariably occur in the zoisite and garnet rocks represent completely altered augite. It will be noticed that the lime removed during this latter reaction would also be available for development of lime-rich secondary silicates. The tremolite, which occurs so plentifully in many of the zoisite rocks, must probably be regarded as a derivative of hornblende; for, while alteration of pyroxene to tremolite has never been observed in any of the rocks of this area, replacement of hornblende by colourless amphibole commonly occurs in the hornblendites and related rocks described in the previous section. The lime-silicate rocks are therefore regarded as much altered gabbros and hornblende-gabbros, comparable with the " rodingites " of the Dun Mountain, Nelson.

Nephrites: Boulders and pebbles of nephrite occur sparsely in the gravels of the Jackson River, while a single specimen (No. 1379) of a rock evidently allied to nephrite was obtained from a boulder alongside the track leading from Martyr Bridge to the Martyr-Jackson Saddle, about one mile north of the bridge. From their distribution and from comparison with other New Zealand occurrences, it is highly probable that these boulders have been brought down from veins in the northern portion of the peridotite belt.

No. 1370 (Upper Ford, Jackson River). Macroscopically the rock is highly schistose, corresponding to the " fissile nephrites " of Finlayson (1909, pp. 367, 368), translucent, and rather pale green in colour, lacking the deep green tint which is so commonly shown by much of the nephrite of New Zealand. In section it is seen to be made up entirely of a colourless fibrous amphibole with the properties of tremolite or actinolite, in minute prisms or fibres which are usually interwoven in tufts and sheaves, in which the form of the individual crystals may often be obscured. It closely resembles sections of nephrite from the Teremakau River in the Otago University collection, and agrees well with the descriptions and figures of typical New Zealand nephrites published by Finlayson (1909, pp. 366-380).

No. 1364 (Upper Ford, Jackson River) is a beautiful pale green translucent highly schistose rock, approaching in appearance the variety termed *inanga* by the Maoris. The hardness, estimated on a polished surface cut parallel to the foliation, is approximately 5.5, and is thus inferior to that of most nephrites, for which the figure 6.5 is usually quoted (e.g., Finlayson, 1909, p. 367). Microscopically the rock consists of slender prisms of colourless tremolite or actinolite, which are often considerably coarser than in the previous specimen, and vary from 0.2 mm. to 0.8 mm. in length. They universally show traces of cross fracture transverse to the direction of elongation. The maximum extinction angle in sections parallel to the vertical axis is 20°, and the optic sign is negative. Only the smaller crystals are grouped in tufts, the larger prisms being perfectly formed and developed independently of any such felted structure.

No. 1379 is a tough, pale greenish grey or almost white opaque rock, much softer than the nephrites described above, and having only poorly developed schistosity. The section consists largely of colourless amphibole, which occurs partly as felted fibres as in section No. 1370, but mainly in the form of much coarser prismatic crystals averaging 0.5 mm. × 0.05 mm., arranged in haphazard fashion. In some parts of the section prisms of amphibole are set in patches of matted, fibrous, very feebly birefringent serpentine. This latter mineral is optically negative, as in the case of antigorite, from which it differs, however, in its small optic axial angle and complete lack of "thorn structure." It thus appears to be similar both in optical properties and in texture to the serpentine of which the Milford Sound bowenite is composed (compare Finlayson, 1909, p. 362). The only remaining constituent of the rock is a cloudy yellowish sphene, occurring in scattered minute irregular granules.

In the paper already quoted, Finlayson (1909, pp. 376, 377) has summarised the various theories which have been put forward to account for the origin of nephrite, the most generally accepted view being that which involves derivation from original pyroxene. He states further that, while uralitisation of pyroxene is the normal mode of origin of most New Zealand nephrite, nevertheless contact-action, deep-seated metamorphism of serpentine-talc-carbonate rocks, and direct transformation of olivine to nephrite have all been responsible for the formation of nephrite in particular instances. The last of these processes is illustrated by a single specimen (Finlayson, 1909, p. 374) believed to have come from the peridotite belt of the Olivine Range, but no such material has since been obtained from this locality by the present writer. Since residual remnants of the primary constituents are completely lacking in the nephrite rocks from the Jackson Valley, it is impossible to be certain as to the nature of the initial rocks from which they originated. From their mineralogical composition and foliated texture it is obvious, however, that shearing stress was one of the main factors involved in their crystallisation.

Veins of Hydrothermal Origin: Under this heading are included veins consisting respectively of chlorite, zoisite, and quartz-albite, which are believed to have been deposited at a late stage, directly from rising magmatic waters.

The first of these three types is represented by specimen No. 1358, which was collected by Dr Moir from a vein of almost pure coarsely crystalline chlorite, 3 cm. to 5 cm. in width, cutting the peridotite of Red Mountain. Macroscopically the mineral is deep green in colour, and occurs in idiomorphic or subidiomorphic hexagonal tables from 1 mm. to 10 mm. in diameter. The section consists almost entirely of well crystallised very pale chlorite, with minor amounts of colourless to pale green serpentine, occupying the interstices between the chlorite crystals. The chlorite is uniaxial and positive, frequently twinned parallel to 001, and in vertical section shows brownish yellow anomolous interference tints when viewed between crossed nicols, indicating weak birefringence and strong dispersion.

In some crystals zones or irregular bands giving Prussian blue interference tints may also be developed. The pleochroism, though faint, is very distinct, and of a type most unusual in chlorites, in that the absorption for light vibrating parallel to the vertical axis (Z) is definitely stronger than that for vibrations parallel to the cleavage.* The pleochroic scheme is

$$X = Y = \text{colourless}$$
$$Z = \text{pale brownish yellow}$$
$$X = Y < Z$$

Basal sections are thus colourless and non-pleochroic. Except for the unusual pleochroism the properties agree perfectly with those of pennine. The serpentine which occurs interstitially between the chlorite crystals is optically positive and nearly uniaxial, and has a lower refractive index but much stronger birefringence than the chlorite. It appears to be chrysotile, but lacks the fibrous habit usually developed in that mineral. Both chlorite and serpentine show strongly undulose extinction, indicating that at the time of crystallisation shearing had not yet entirely ceased.

No. 1407 is a hard white rock collected by Dr Moir from a vein in the serpentine east of Big Bay in the Red Mountain area. Over 95% of the rock consists of fairly coarsely crystalline zoisite in subidiomorphic or allotriomorphic crystals ranging from 0.5 mm. to 1 mm. in diameter. The optic axial plane is parallel to the 010 cleavage, and the elongation of prismatic crystals is always negative, properties corresponding with iron-free or alpha-zoisite (Winchell, 1927, p. 354). There are scattered crystals of a uniaxial, optically positive serpentine with micaceous habit, identical with the variety already described in the altered chromite-pyroxene rock No. 1361. The serpentine of the chlorite-rock No. 1358 just described is also probably of this type. Interstitial albite occurs as an accessory. It is admittedly possible that this zoisite vein may be a completely altered anorthosite, and thus comparable with the zoisite-bearing rocks of the " altered gabbro " group. The appearance of the rock, both in hand-specimen and beneath the microscope, nevertheless strongly supports the view that the zoisite has been deposited directly from aqueous solution. Minute veinlets of similar composition, which appear almost certainly to have been formed in this manner, have already been noted cutting some of the more highly altered rocks of the peridotite belt.

A narrow dyke of intensely sheared quartz-albite rock (No. 1255) invading the peridotite mass on the north side of Woodhen Creek Gorge has already been recorded (Turner, 1930a, p. 195), and compared with closely similar rocks described by Benson (1914, p. 691) from the Great Serpentine Belt of New South Wales. The presence of this rock, deep within the heart of the peridotite intrusion, indicates that aqueous solutions rich in soda and silica must have been expelled from the underlying magma towards the close of the period of intrusive activity. Benson (1914, p. 691; 1918, p. 715) mentions a number of cases where similar emission of sodic solutions from peridotite magmas has been recorded, and calls attention to albitisation of mica-schists of the Maniototo Series adjacent to a serpentine dyke in the vicinity of Cromwell, Central Otago, observed by Park (1908). It may be pointed out that the Cromwell serpentine is probably of the same age as the peridotites of the Olivine Range of Westland.

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* A chlorite having closely similar properties has recently been described as a constituent of altered peridotites from Northern Norway by S. Foslie (*Norsk. geol. tids.* B. xii, 1931, pp. 219-245).

Epidote-hornfelses: The western flank of the peridotite belt is bordered by a zone of epidote-hornfelses, which have apparently been produced by contact action of the peridotite upon the adjacent biotite-hornfelses of the Metamorphic Series. Owing to the fact that the outcrop is obscured by dense forest, the exact extent of this zone has not been determined, but specimens have been collected close to the contact on both Martyr and Red Spurs, and from boulders in Martyr Creek. Epidote-hornfelses appear to be absent from the eastern margin of the peridotite belt.

No. 1359 (boulder, Martyr Creek) is a very fine-grained green rock, minutely laminated but only imperfectly fissile, and breaking with the rather even fractive characteristic of finely crystalline hornfelses. The essential constituents are epidote 40%, albite-quartz 40%, muscovite 10%, and chlorite 10%. The grain-size is remarkably uniform, about 0.05 mm., but there is a tendency towards porphyroblastic development of albite, some crystals of which reach 0.1 mm. or 0.2 mm. in diameter. The banding is due to alternation of ill-defined laminae 1 mm. to 5 mm. in width, in which epidote is concentrated or diminished respectively. The epidote is a yellow, highly birefringent ferruginous variety. Pale green chlorite and colourless sericite occur abundantly as minute flakes and wisps, lying interstitially between the grains of the other minerals. The relative proportions of quartz and albite are difficult to determine, since interstitial chlorite and mica prevents application of the Becke refractive index test. There are several fair-sized grains of magnetite.

No. 1360 (Red Spur, west of peridotite contact) is similar to the previous specimen, but somewhat more fissile. Yellow epidote is even more plentiful than in the preceding section, and occasionally occurs as large grains ranging up to 0.2 mm., set in the usual fine-grained matrix of epidote, albite, quartz, and chlorite. One of the laminae contains a number of xenoblastic grains of strongly pleochroic deep green hornblende. Sphene and magnetite occur as minor accessories.

The high epidote content of the hornfelses suggests that lime-bearing solutions emitted from the cooling intrusion must have been active during their crystallisation. The transformation of coarsely crystalline biotite-oligoclase hornfelses and schists into fine-grained epidote-hornfelses containing albite, sericite, and chlorite involves breaking down of a mineral assemblage characteristic of a relatively high grade of metamorphism to a typically low-grade assemblage. From the mineralogical composition of the contact rock it therefore follows that the intrusion of the peridotite mass was affected under low-grade metamorphic conditions.

In conclusion it may be pointed out that the epidote-hornfelses of the Olivine Range recall similar rocks described by Greenly (1919, pp. 108, 109) from the contact aureole which surrounds some of the serpentines of Anglesey.

Tectonic Significance and Date of Intrusion: In his report of 1887, Professor Park stated that the peridotite mass of Red Mountain had risen up along a great fault plane, separating the Maniototo schists of Central Otago from the breccias of the overlying Te Anau Series further west. In the present area (Turner, 1930a, p. 199) intrusion has been effected along a major fault which runs north-east along the middle portion of the Cascade Valley, and continues down the full length of the Jackson for at least ten miles beyond the north-eastern end of the peridotite belt. This fault has been referred to elsewhere in this paper as the Cascade-Jackson Valley Fault. On the Olivine Range the south-eastern margin of the intrusion dips steeply south-east. Judging from the relative intensity of metamorphism exhibited by the rocks on either side of the Jackson Valley, the upthrow is on the north-western side of the fault.

It has already been shown that intrusion of the peridotite mass and associated dykes was accompanied by shearing movements, which continued to operate throughout the subsequent period of hydrothermal alteration. This accords with the generalisations advanced by Benson (1926) regarding the tectonic conditions accompanying the intrusion of ultrabasic rocks, and with Suess's (1909, p. 564 view that " the green rocks are sills in dislocated mountains which sometimes follow the bedding planes and at others the planes of movement."

In considering the probable age of the South Westland peridotites, it is necessary also to take into account the available evidence bearing upon the age of other ultrabasic intrusions of the South Island, since these in all probability belong to a single orogenic period (e.g., see Finlayson, 1909, pp. 364, 365; Benson, 1926, p. 44). As pointed out by Finlayson, there is a strong petrographic similarity between all these rocks, while all have been considerably affected by subsequent shearing during serpentinisation. This similarity is all the more apparent when the South Island peridotites are contrasted with the early Tertiary serpentines and peridotites of North Auckland. In the second place the ultrabasic masses of Nelson, Central Westland, and South Westland are all linear intrusions, which lie west of and parallel to the main axial mountain chain. Where the main arc of folding bifurcates in the southern portion of the South Island (Benson, 1924, p. 129), other linear intrusions of ultrabasic rocks, according to the observations of McKay (1881, p. 143) and Marshall (1906), continue to be developed on the western side of the Central Otago fold in the rugged country between Lake Wakatipu and the Hollyford River. Thus as pointed out by Finlayson (1909, p. 365) " the structural significance of the magnesian belt is too evident to be overlooked in this connection."

Discussing the age of the peridotites of the South Island, Benson (1926, p. 44) sums up the situation thus: " The upper limit of the possible age of these beds is fixed by the occurrence of pebbles of serpentine in the ' Miocene ' beds overlying the ancient rocks (Morgan, 1908) . . . During the last decade the ultrabasic and accompanying basic intrusions have been generally considered to have been injected during the late Mesozoic orogeny, but more recently Park (1921) has declared his belief that they were injected during the early part of the Triassic, accompanying the orogeny he believes to have occurred then, and he considers that all other occurrences in the South Island are probably of the same age.'' During the interval extending from the Middle Cretaceous to the later part of the Tertiary, the South Island of New Zealand was not affected by folding movements of any importance, and it is thus safe to conclude that the ultrabasic intrusions of the South Island are certainly not younger than Lower Cretaceous. Furthermore, since as stated above the trend of the peridotite intrusions approximates to that of the ancient folds, and since the latter are believed to be products of the great Lower Cretaceous orogeny, it is reasonably certain that the intrusions themselves are of Lower Cretaceous age.

Earlier in this paper the suggestion was put forward that the main metamorphism of the schists and gneisses of Central Otago and Westland may have occurred in conjunction with folding movements much more ancient than those of the Lower Cretaceous. If it be admitted that the ultrabasic intrusives of the South Island are not younger than Lower Cretaceous, additional evidence in support of this hypothesis may now be brought forward. In the first place it has already been established that in the Cascade-Haast area uprise of a subjacent granite batholith accompanied the metamorphism during the period of its maximum intensity. Intrusion of the peridotite mass took place at a much later date, when meso-zone conditions of metamorphism had given place to conditions typical of the epizone. If both granites and peridotites belong to the same intrusive cycle, then the well-established principle of decreasing basicity of successive intrusions is reversed in this instance. In the second place the distribution of granites and peridotites has considerable significance in this connection. During a folding movement, linear intrusions of peridotite usually rise up at an early stage, in the outer portion of the folded range, while masses of granite normally invade the core of the fold at a somewhat later stage (e.g., Benson, 1926, p. 76). The distribution of the ultrabasic intrusives of the South Island along the outside of the main arc of folding agrees perfectly with this principle, but if the granites belong to the same orogenic cycle they should lie within, i.e., east of the peridotite line. Actually the reverse is always the case.

The writer therefore concludes that the peridotite intrusions of the South Island are probably of Lower Cretaceous age, and that the progressive metamorphism of the schists of Otago and Westland and accompanying uprise of granite intrusions belong to a distinct and much more ancient period of orogeny. The partial retrogressive metamorphism of some of the schists and hornfelses of the Cascade and Arawata Valleys are attributed to the same shearing forces as affected the peridotite mass immediately after intrusion in Early Cretaceous times.

DIORITIC ROCKS.

The dioritic rocks are confined to the area of hornfelses and schists which lies south of the Arawata River, between Laschelles Creek and the Jackson Valley, where they occur as minor dykes and as boulders in the stream beds. Their precise age is unknown, but as they are only slightly affected by shearing, it is reasonably certain that they post-date the much more highly altered ultrabasic rocks.

The essential constituents of these rocks are brown or green hornblende and plagioclase (ranging from oligoclase to andesine), in more or less equal proportions, always accompanied by a notable amount of interstitial quartz. In one specimen (No. 1393) augite, biotite, and ilmenite are also plentiful. The accessory minerals include extremely abundant apatite, variable amounts of iron ores, and minor sphene. Most of the dioritic rocks have suffered considerable alteration—probably of an auto-pneumatolytic kind—involving partial chloritisation of hornblende and biotite, sericitisation of feldspar and crystallisation of minor amounts of secondary calcite, epidote, and sphene.

One of the least altered of these rocks is specimen No. 1333 collected from a narrow dyke which invades the hornfels on the southern side of the Arawata River, 1½ miles west of the mouth of the Jackson. It is a holocrystalline, rather fine-grained non-porphyritic rock, consisting of feldspar 55%, hornblende 35%, quartz 5% to 10%, and accessory apatite, magnetite, and pyrite. The hornblende is for the most part a brown variety occurring in perfectly idiomorphic crystals about 0.8 mm. long (Pl. 28a, Fig. 16), which often show simple orthopinacoidal twinning, and have a maximum extinction angle (Z to c) of 20°. The pleochroic scheme is

X = light yellowish brown
Y = deep yellowish brown
Z = deep yellowish brown
$X < Y < Z$

The crystals are frequently rimmed with a narrow border of deep green to very pale yellowish hornblende, while in some instances an almost colourless or very pale green amphibole partially replaces the normal coloured mineral. Pale green pennine occurs as an alteration product of hornblende, but it not nearly so plentiful as in some of the other dioritic rocks from this area. The feldspar is oligoclase-andesine approximating to $Ab_{70}An_{30}$, and occurs in slightly sericitised, subidiomorphic or allotriomorphic crystals, about 0.5 mm. in diameter, enclosing or enwrapping the hornblendes. Quartz occurs as highly irregular interstitial grains among the crystals of feldspar and hornblende.

A much more altered type, briefly described in the previous paper dealing with this area (Turner, 1930a, p. 200), is represented by boulders from Laschelles Creek (Nos. 1262, 1392), and from the small creek which joins Martyr Creek about 1½ miles above its junction with the Cascade River (No. 1263). The hornblende crystals average about 3 mm. in length, and are perfectly idiomorphic.

They are often simply twinned, and show strong pleochroism according to the following scheme:—

X = pale yellowish brown
Y = dark yellowish brown
Z = dark brown, sometimes with a distinct reddish tinge
$X < Y < Z$

As in the previous section, the brown hornblende crystals are usually rimmed with a fringe of green hornblende. Partial or complete alteration of the amphibole to deep green pennine, often enclosing grains of secondary sphene or calcite, is common in all the rocks of this type. The feldspar appears to be mainly medium oligoclase, but since it is almost completely replaced by sericitic mica it is impossible to determine the composition exactly. Alkali feldspar is probably also present in subsidiary amounts. Quartz is relatively abundant, both as interstitial grains and very commonly as a micropegmatitic intergrowth with the feldspar. Slender prisms of apatite ranging up to 3 mm. in length are very plentiful, while the iron ores include both magnetite and pyrite. Calcite and deep yellowish green epidote are sometimes associated with the chlorite.

No. 1393 (boulder, Laschelles Creek) is unusual in that the ferromagnesian constituents include abundant augite and biotite as well as hornblende. The mineral composition is feldspar 40%, augite 20%, hornblende 15% to 20%, biotite 5% to 10%, quartz 5% to 10%, ilmenite 5% to 10%, apatite 1%, accessory sphene, and secondary calcite. The feldspar is largely basic andesine, in well-twinned subidiomorphic crystals which are usually considerably altered to sericite. This is accompanied by minor amounts of sericitised alkali-feldspar. The quartz occurs mainly as interstitial grains, but occasionally it may be intergrown on a fine scale with the feldspar. The most abundant ferromagnesian silicate is pale pink relatively unaltered augite, which typically takes the form of rounded allotriomorphic crystals, rarely showing marginal reaction rims of hornblende or biotite. It sometimes ophitically encloses laths of plagioclase. The hornblende is almost entirely the pale yellow to deep green variety, and is considerably altered to pennine. It occasionally shows marginal resorption to biotite. The latter mineral is in the form of ragged flakes from 0.1 mm. to 0.3 mm. in length, with very strong pleochroism from pale golden brown to very deep chocolate brown (almost black), and is sometimes partially replaced by pennine. Ilmenite in skeletal crystals, rods, and parallel growths is unusually plentiful, while slender prisms of apatite are constantly present in all parts of the section.

No. 1264, obtained from boulders in the Cascade River, is an unusually coarse-grained rock consisting of large idiomorphic crystals of pale green hornblende from 3 mm. to 4 cm. in length, and occasional coarse apatite grains, enclosed in a mass of completely altered plagioclase, which appears to have been andesine.

No. 1327 is an extremely fine-grained rock macroscopically resembling a fine hornfels, obtained *in situ* from a small dyke invading the hornfels on the south side of the Arawata River, 1½ miles west of the Jackson. The rock consists of a holocrystalline groundmass of completely altered feldspar and hornblende, the grain-size of which ranges from 0.01 mm. to 0.05 mm., enclosing rare phenocrysts of acid andesine near $Ab_{65}An_{35}$ in composition. Secondary calcite is developed throughout the groundmass, and there are several inclusions consisting of relatively coarse aggregates of quartz and calcite grains. The rock is classed as an unusually fine-grained porphyrite.

With the exception of the porphyrite just described the dioritic rocks are believed to be of pegmatitic origin, having crystallised from a residual dioritic magma unusually rich in soda and potash, and in water and other volatile constituents. They are therefore classed as quartz-diorite-pegmatites.

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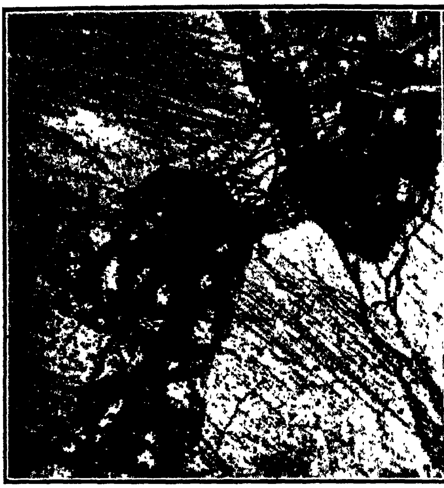

FIG. 13.—*Diallage and interstitial olivine in pyroxenite (No. 1376).*

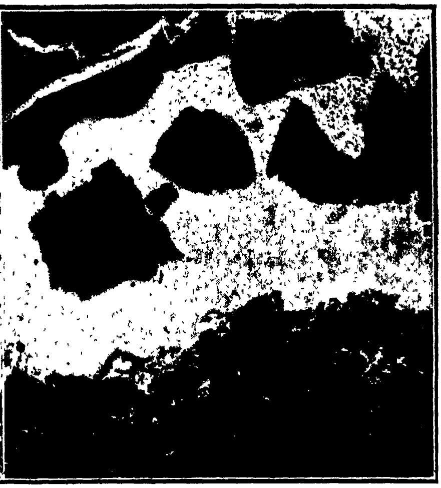

FIG. 14.—*Contact between partially serpentinised peridotite and chromite vein (No. 1374a).*

FIG. 15.—*Hornblende-albite rock (No. 1412).*

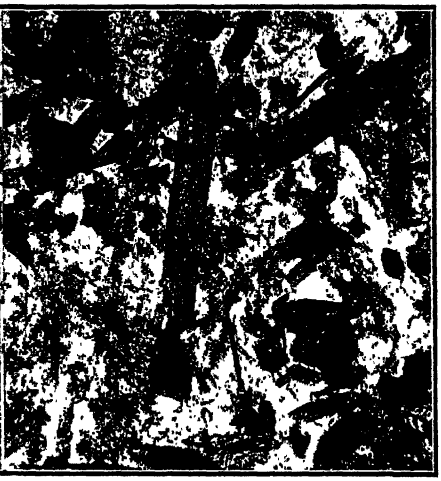

FIG. 16.—*Fine-grained diorite-pegmatite (No. 1333).*

All magnifications 37 diameters.

The Mobilities of Ions and Electrons in Pure Gases.

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PURPOSE.

THE purpose of this paper is to compare the general mobility equations advanced by Langevin and by Compton, and to apply them to certain cases for the motion of electrons and positive ions in pure gases. Some aspects of the present state of our experimental and theoretical knowledge of the mobilities and nature of gaseous ions are discussed.

PART I.—MOBILITIES OF IONS IN PURE GASES.

1.—Experimental Methods:

In *Conduction of Electricity Through Gases* (1) Sir J. J. Thomson and G. P. Thomson describe eleven distinct methods for measuring the mobility of ions in gases. Some of these have proved much more satisfactory than others, and within the last few years a modification of one of them—Tyndall and Grindley's method (2)—has in the hands of Tyndall and his collaborators, and of Bradbury (3), yielded very valuable results. Tyndall and Grindley produce periodic flashes of ionization by a commutator which controls the electric field of rectangular wave-form between the measuring plates. The ionization is produced near one plate by a strip of polonium placed on a rotating wheel on the same shaft as the commutator. Laporte (4) has used a method similar in principle, but the flashes of ionization produced by the polonium are controlled by mechanical means, instead of by a commutator. He employed two similar circular discs with radial slits, rotating on a common axis. For mobility determinations in pure gases these methods (employing a polonium source) are unsuitable, for it has not been possible to devise such an apparatus in metal and glass which can be thoroughly " baked out " and evacuated in order to eliminate gaseous impurities almost completely. Hence arises the importance of two methods developed from these periodic flash methods. They are identical in principle, and were independently devised by Van de Graaff (5), and by Tyndall, Starr, and Powell. (6). The ions are admitted to the constant field and from it to the collecting chamber by means of properly timed alternating potentials actuated by commutators, transformers, or valve oscillators. Some preliminary experiments with negative ions in moist air performed by Van de Graaff and the author (7) served to demonstrate the principle of the method, which has been used by Van de Graff (5) to measure the mobility of positive ions in hydrogen. Tyndall and his collaborators refer to their method as the " Four Gauze " method. The advantages they claim for it, which apply likewise to Van de Graaff's method, are that the apparatus can be made airtight, that the method has a higher resolving power than Tyndall and Grindley's method, that the time of measurement is shorter, and, in addition, the ions may be given any required age within wide limits. An attempt was made to prevent the interpenetration of the constant field and the field for introducing the ions. This method is not an absolute one, and compared with Van de Graaff's has the disadvantage that the ions are derived from polonium within the apparatus, so that there is grave risk of contamination when " baking out " the apparatus. Van de Graaff used a glow discharge from a needle point for the source of ions. Although this device may produce some metastable atoms, it has obvious advantages, and thus has been adopted by other experimenters, e.g., Tyndall and Powell (8).

Tyndall and Powell (9) have modified the " Four Gauze " method to enable it to be used with pure gases at pressures far below atmospheric. In addition to the fairly high resolving power for ions of different mobilities which had already been attained, the new apparatus was constructed entirely of pyrex glass and metal so that it could be subjected to a rigorous heat treatment in accordance with the requirements of modern vacuum technique. The apparatus was still unsatisfactory in some ways, viz., only relative mobilities could be measured, and as a polonium source was used to produce the ionization the whole apparatus could not be heated to a sufficiently high temperature to bake it out effectively. Although gaseous impurities could not be completely eliminated, the mobility value observed for the fastest positive helium ions in helium was more than double that of any previous observer.

In 1931 Tyndall and Powell (8) made further modifications to their apparatus in order that (1) absolute mobilities could be measured; (2) a glow discharge could be used for the ion source; and (3) low gas pressures could be used in order to reduce the effect of small traces of impurity. As this apparatus could be " baked out " as a whole at 550° C. while it was thoroughly evacuated, the chance of contamination of a very pure gas introduced into it was much reduced.

Other methods have been used recently which do not lend themselves so well to work with very pure gases. Loeb (10) has used an alternating current method by which he obtains absolute values of mobilities. He claims that with it there are no disturbing effects due to the use of gauzes, and that the ions definitely emerge from one plane of the parallel-plate electrode system. Zeleny (11) has used his blast method to study ions of moderate age in air with water vapour present.

2.—Recent Results from Mobility Experiments:

In 1930 Tyndall and Powell (9) gave adequate reasons for their conclusion that in none of the experiments made before that time on the mobility of ions had the gas under examination been spectroscopically pure. "In such conditions," they pointed out, "in a given gas the ions may well consist of clusters of which the size and mass vary from one experiment to another. The reason why many observers have found the negative ions to be of molecular magnitude and not electrons in nitrogen, hydrogen, etc., becomes obvious, and it is not surprising that the actual mobilities found are smaller than those calculated theoretically from the standpoint of the classical dynamical theory of gases, assuming the ions to be monomolecular." It is no exaggeration to say that this paper marked the commencement of a new era in the subject, and it is partly to draw attention to the importance of some aspects of the change that this paper has been prepared. These experimenters showed that the effects of impurities in the case of positive ions are even more critical than with negative ions, and in this they have been supported by Zeleny's work (12) on the ageing of ions in air and in nitrogen, and by recent experimental determinations of the mobilities of positive ions. The enormous difference in the mobility values found in the new experiments and those previously accepted can be illustrated by the case of positive ions in helium. In 1907 Franck and Pohl obtained the value 5.09 (cm./sec. per volt/cm.) at atmospheric pressure in this gas, and in 1928 J. S. Rogers obtained values ranging from 5.6 to 6.7. In 1930, however, Tyndall and Powell found evidence for the existence of positive ions in helium with mobilities as high as 17, and a year later they definitely obtained the value 21.4 at 20° C., which they consider to be accurate to 1 per cent. For the mobility of positive ions in hydrogen, Zeleny obtained the value 6.70 and Van de Graaff 5.8. It is probable that when experiments are conducted in the pure gas, values much in excess of these will be obtained. Bradbury (2) has already obtained evidence of positive ions with a mobility of 13.6. Loeb (10) in 1931 obtained values for positive ions, presumably of sodium, in hydrogen and in nitrogen. Provided their life did not exceed 10^{-4} sec., the mobilities at 0° C. were found to be 17.5 and 3.75 respectively. The possible error in this work was high on account of an uncertain temperature correction introduced by the temperature gradient from the Kunsman source through the gas. This error did not exceed 10 per cent. Bradbury (2) has confirmed some of Loeb's results by Tyndall and Grindley's method. In hydrogen Loeb found for the normal positive ion a value 8.4, and for an intermediate ion of fairly short life a value 13.5, both at 0° C. Definite evidence for the existence of these two types of ion was obtained by Bradbury, but the detection of the highest mobility ion (17.5) was beyond the limits of his method. Bradbury used hydrogen ions generated by an intense beam of hard X-rays in his experiments instead of sodium ions, so there is little change in mobility of these two types of ion due to change in nature of the original ion. This is to be expected if the normal ions are clusters, and if the intermediate ion is formed by the attachment of an impurity molecule to the original ion, or by the exchange of an electron between an impurity molecule and the original positive ion. In their most recent paper Tyndall and Powell (13) have obtained accurate values for the mobilities of the alkali ions in argon, neon, and helium. The Kunsman sources were cooled by circulating water, so that the resulting temperature variation of the gas was of the order of the room temperature variation, and could be neglected, as the resultant error was probably less than 1 per cent. These experimenters (14) have also measured accurately the ratio of the mobility of the positive mercury ion to the positive helium ion in helium at 20 mm. pressure, for which they obtain the value 0.55.

In the light of these recent experiments at least three of the six chief generalizations which had emerged from investigations made prior to 1928 (reference (1), page 156), will need revision. These three are:—

(1) The mobility of the ions, especially in the lighter gases, is much less than it would be if the ion consisted of a single molecule, having the same free path as an uncharged ion.

(2) The mobility of the ions depends only on the gas through which they move, so that though in a mixture of gas there may be ions of different kinds all the ions of the same sign have the same mobility.

(3) In the lighter gases the mobility of the negative ions is greater than that of the positive.

The considerations which led Tyndall and Powell to the conclusion that no significance can be attached to the values of the mobilities of positive ions determined before 1930 demand attention. The positive ions attain very small terminal energies as compared with electrons under similar conditions, and the monomolecular or atomic ions which are the primary products of the action of the ionizing agent may be replaced in the presence of extremely small concentrations of foreign molecules by others of an entirely different nature. Any or all of the following processes may be involved:—

(1) A cluster round the positive ion may form as the result of its impact with a foreign molecule possessing a marked dipole.

(2) A positive ion may capture an electron from any molecule or atom of lower ionization potential with which it collides.

(3) Metastable atoms may be produced in the process of ionization.

Evidence in support of the second process is now strong, and it is probably of paramount importance in many experiments, for it accounts satisfactorily for the marked effect on the mobility obtained in the presence of minute quantities of even non-polar impurity. The possibility that this process might alter to a large extent the nature of the ions being measured was ignored until a few years ago.

3.—General Mobility Equations:

Langevin (15) has given the most satisfactory general theory for the mobility of ions in gases. This is based on rigorous mathematical investigations introduced into the kinetic theory of gases by Maxwell and Boltzmann. Hassé (16) pointed out the fundamental importance of Langevin's paper. He made a recalculation of the numerical part of it, and embodied his results in a more convenient and accurate form (Table III of Hassé's paper). Langevin considers the ions to be conducting spheres of mass M and charge e (the charge on an electron) moving under the influence of an external field in a gas whose molecules (mass m) have a high concentration (N per unit volume) compared with that of the ions. Let ρ be the density of the gas and D its dielectric constant. If a is the "electrical radius" of the molecule and r the distance between the centres of the molecule and ion, then the attractive force between the ion and the molecule due to the induced charge on the latter is equal to

$$\frac{e^2a^3\,(2r^2 - a^2)}{r^3\,(r^2 - a^2)^2},$$

which reduces to $2e^2a^3/r^5$ when r is assumed to be large compared with a. (J. J. Thomson *Elements of the Mathematical Theory of Electricity,* 5th Edition, page 114.) It has been shown by J. H. Jeans *(Mathematical Theory of Electricity and Magnetism,* page 131) that $D - 1 = 4\,\pi\,Na^3$. Hence the force of attraction is given by

$$F = \frac{(D-1)\,e^2}{2\,\pi\,Nr^5}\,\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

and in the approximation we have underestimated this force in the ratio 1 to $(1 + \frac{3}{2}\,a^2/r^2)$. Langevin considers two cases: (1) when the molecules are perfectly elastic spheres, and (2) when in addition the molecules exert attractive forces of the type given by Eq. (1). This consideration is only a first approximation to the rigorous and complicated mathematical treatment based on the kinetic theory of diffusion, but it happens to be a very good one in this case. Langevin arrives at the general mobility formula

$$k = \frac{A}{\sqrt{\rho\,(D-1)}} \times \left(1 + \frac{m}{M}\right)^{\frac{1}{2}}\,\ldots\ldots\ldots(2)$$

where A is a numerical coefficient, whose value depends on the comparative effect of the attractive forces and the elastic collisions. Write

$$\lambda^2 = \frac{8\,\pi\,p\,\sigma^4}{(D-1)\,e^2}\,\ldots\ldots\ldots\ldots(3)$$

where p is the pressure of the gas and σ is the distance between the centres of the molecule and the ion at the instant of collision, i.e., the value of r during a collision. Then A was calculated as a function of λ by Langevin, and the result was confirmed by Hassé. There are two limiting cases:

(1) When the attracting forces are negligible, in which case λ is large and the product λA approaches $\frac{3}{4}$. Substituting for $(D - 1)$ from Eq. (3), we can write Eq. (2).

$$k = \lambda A \frac{e}{\sigma^2 (8 \pi \rho p)^{\frac{1}{2}}} \left(1+\frac{m}{M}\right)^{\frac{1}{2}} \ldots\ldots\ldots\ldots (4)$$

In this limiting case we have

$$k = \tfrac{3}{4} \frac{e}{\sigma^2 (8 \pi \rho p)^{\frac{1}{2}}} \left(1+\frac{m}{M}\right)^{\frac{1}{2}} \ldots\ldots\ldots\ldots (5)$$

(2) The attractive forces are of much greater importance than the collisions when λ is small, due to either σ being small or $(D - 1)$ large. In this case A tends to the value 0.505 and λA to zero. Between these limits A is a continuous single-valued function of λ with a maximum value of about 0.590 for $\lambda = 0.6$.

One of the best established generalisations emerging from experiments on ionic mobilities is that the mobility of the positive ion at constant temperature varies inversely as the pressure. This law holds also for negative ions over a more limited pressure range. Since according to the usual theory of dielectrics $(D - 1)$ varies as p, we deduce from Eq. (3) that λ, and so A, is independent of p. Eq. (4) then shows that k is inversely proportional to p. According to this theory the mobility is independent of the electric field (X volt per cm.), unless this influences the dielectric constant, which effect would be expected to be small.

Hassé has drawn attention to the rigorous methods which have been applied by Chapman and by Enskog to the kinetic theory of gases. In the case of elastic collisions the equation for the diffusion of gases, and hence Eq. (2) which has been derived from it, gives results about 13% too low, but the equation is exact in the other extreme case when we are dealing only with forces varying inversely as the fifth power of the distance. For intermediate cases, where both collisions and attractive forces are operative, the correcting factor will be between 1.00 and 1.13, but its value cannot be determined in the present state of theoretical knowledge. In most of the calculations, for which we use Langevin's equation, $\lambda < 1$, so that the correcting factor is not likely to exceed about 1.05.

In their recent review—*Electrical Discharges in Gases*—K. T. Compton and I. Langmuir (17) deal with the question of the mobilities of ions and electrons in so far as they concern this subject. As it is clear that most of this section is due to Compton, I will ascribe it all to him for convenience. On the basis of the kinetic theory of gases, and assuming elastic collisions between ions and molecules, Compton, after allowing for the phenomenon of persistence of velocity, arrives at a general mobility equation which should apply to ions and electrons. Apart from some changes in notation and the elimination of numerous typographical errors, his treatment is used in what follows. The terminal speeds of charged particles in the direction of the uniform electric field (X) are calculated by equating the rate of gain to the rate of loss of energy of the particle. In advancing a distance dx in the direction of the field each particle of charge e receives energy $edU = eXdx$, where U is the kinetic energy of a unit-charged particle in terms of equivalent potential drop. In the path dx the particle will lose energy $vfeUdx$, where v is the average number of collisions made while advancing unit distance and f is the average fraction of its energy lost at a collision as a result of momentum transfer. Hence the net rate of gain of energy by the particle is

$$e\frac{dU}{dx} = e\,(X - vfU).$$

The terminal energy U_t is the value of U when $\frac{dU}{dx} = 0$

Therefore $$U_t = X/vf \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

If we write $eU_t = E_1$, and $e\Omega = E_2$ for the mean energies of charged particle (mass M) and gas molecule (mass m) respectively, Compton shows that

$$v = \frac{2\,U_t}{\lambda_0^2\,X} \quad\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where λ_0 is defined by $1/\lambda_0 = \pi\,N\,\sigma^2$. It is to be noted that λ_0 is not in general the mean free path of the particles, but it is the free path the particle would have if its speed was very large compared with the speed of the molecules. The fraction of the energy lost at a collision between an ion and a molecule at rest, where both are treated as elastic spheres, is known to be $f = 2mM/(m + M)^2$. When the molecules are also in motion the average fraction of the energy lost is less than this. In the general case of particles with Maxwellian velocity distributions Cravath (18) has shown

$$f = \frac{2.66\,m\,M}{(m+M)^2} \times \left(1 - \frac{E_2}{E_1}\right) \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Substitute from Eqs. (7) and (8) for v and f in Eq. (6)

$$U_t = \frac{X}{vf} = \frac{X^2\,\lambda_0^2\,(m + M)^2}{2\,U_t \times 2{\cdot}66\,mM} \cdot \frac{E_1}{E_1 - E_2}$$

But $$\frac{E_1}{E_2} = \frac{U_t}{\Omega}$$

therefore $$U_t = \frac{X^2\,\lambda_0^2\,(m + M)^2}{5{\cdot}32\,U_t\,mM} \cdot \frac{U_t}{U_t - \Omega}$$

Hence $$U_t^2 - \Omega\,U_t - A = 0$$

where $$A = \frac{X^2\,\lambda_0^2\,(m + M)^2}{5{\cdot}32\,mM}.$$

Solve for U_t.

$$U_t = \tfrac{1}{2}\,\Omega + (\tfrac{1}{4}\,\Omega^2 + A)^{\frac{1}{2}} \ldots\ldots\ldots\ldots(9)$$

This is of the right form, for it reduces to the equipartition value $U_t = \Omega$ for weak fields $X = 0$.

The kinetic theory of diffusion leads to the mobility equation

$$k = \frac{0{\cdot}921\, e\lambda_0}{MC} \left\{ 1 + \frac{E_2 M}{E_1 m} \right\}^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where C is the root mean square velocity of the ions. This is comparable with the most familiar mobility equation, the simplified Langevin equation,

$$k = \frac{0{\cdot}815\, e\lambda_0}{MC} \left\{ 1 + \frac{M}{m} \right\}^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

The difference in the numerical factor arises from a different method of averaging used by Compton, and the absence of the ratio of the mean energies in Langevin's equation arises from an implicit assumption of equipartition of energy.

Eqs. (9) and (10) are the basis of Compton's general mobility equation. Since $eU_t = E_1 = \frac{1}{2} MC^2$

$$C = (2eU_t/M)^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Substitute from Eqs. (9) and (12) for C and U_t in the mobility Eq. (10) and we have

$$k = \frac{0{\cdot}921\, e\lambda_0}{(2\, e M U_t)^{\frac{1}{2}}} \left[1 + \frac{M\Omega}{m U_t} \right]^{\frac{1}{2}}$$

$$= \frac{0{\cdot}921\, e\lambda_0}{(2\, e M)^{\frac{1}{2}}} \left\{ \tfrac{1}{2}\,\Omega + \left[\tfrac{1}{4}\Omega^2 + \frac{\lambda_0^2 X^2 (m+M)^2}{5{\cdot}32\, m M} \right]^{\frac{1}{2}} \right\}^{-\frac{1}{2}}$$

$$\times \left\{ 1 + \frac{M}{m} \cdot \frac{1}{\tfrac{1}{2} + \left(\tfrac{1}{4} + \frac{\lambda_0^2 X^2 (m+M)^2}{5{\cdot}32\, m M \Omega^2} \right)^{\frac{1}{2}}} \right\}^{\frac{1}{2}} \ldots (13)$$

This is Compton's general mobility equation. In this equation the second bracket term replaces the factor $(1 + M/m)^{\frac{1}{2}}$ in the usual mobility equations. The change allows for the influence of persistence of velocities. The first term in brackets reduces to the equipartition value of the energy Ω, when X is small. For the two cases of chief interest Eq. (13) takes particular forms. For monomolecular ions $M = m$, and $\lambda_0 = \sqrt{2}.\lambda_1$ where $\lambda_1 =$ molecular mean free path. Hence

$$k = \frac{0{\cdot}921\, e\lambda_0}{(2\, e M)^{\frac{1}{2}}} \left\{ \tfrac{1}{2}\Omega + \left(\tfrac{1}{4}\,\Omega^2 + \frac{\lambda_0^2 X^2}{1{\cdot}33} \right)^{\frac{1}{2}} \right\}^{-\frac{1}{2}}$$

$$\times \left\{ 1 + \frac{1}{\tfrac{1}{2} + \left(\tfrac{1}{4} + \frac{\lambda_0^2 X^2}{1{\cdot}33\, \Omega^2} \right)^{\frac{1}{2}}} \right\}^{\frac{1}{2}} \ldots\ldots (14)$$

For electrons $M \ll m$, and $\lambda_0 =$ electron mean free path. Hence

$$k = \frac{0{\cdot}921\, e\lambda_0}{(2\, e M)^{\frac{1}{2}}} \left\{ \tfrac{1}{2}\Omega + \left[\tfrac{1}{4}\Omega^2 + \frac{\lambda_0^2 X^2 m}{5{\cdot}32\, M} \right]^{\frac{1}{2}} \right\}^{-\frac{1}{2}} \ldots\ldots\ldots (15)$$

4.—Calculation of Mobilities and Comparison with Experimental Results:

Eq. (14) can be simplified as follows:—

$$\lambda_0 = \sqrt{2}\,\lambda_1 = \sqrt{2}\,\frac{\lambda_2}{p}\,\frac{T}{273}$$

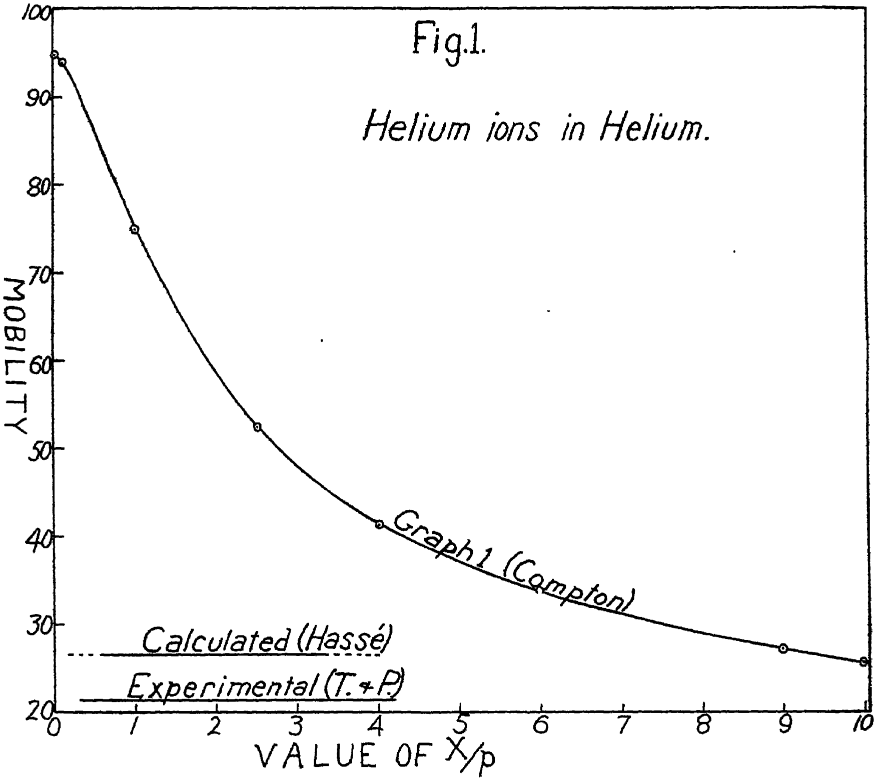
and

$$\Omega = \frac{E_2}{e} = \frac{E_0}{e}\,\frac{T}{273}$$

where λ_2 = molecular mean free path at 0° C. and 1 mm. pressure, E_0 = mean molecular kinetic energy at 0° C., T is the absolute temperature and p is the gas pressure in mm. of mercury. Since $E_0 = 5{\cdot}62 \times 10^{-14}$ ergs and 1 electron-volt $= 1{\cdot}59 \times 10^{-12}$ ergs, therefore $\Omega = 3{\cdot}54.10^{-2} \times \frac{T}{273}$ electron-volts. Substituting for λ_0 and Ω in Eq. (14), we obtain

$$k = \frac{0{\cdot}873 \times 10^{-5}}{M^{\frac{1}{2}}} \cdot \frac{\lambda_2}{p} \cdot \left(\frac{T}{273}\right)^{\frac{1}{2}} \left\{1 + \left[1 + 4800\left(\frac{\lambda_2 X}{p}\right)^2\right]^{\frac{1}{2}}\right\}^{-\frac{1}{2}}$$

$$\times \left\{1 + \frac{2}{1 + \left(1 + 4800\left(\frac{\lambda_2 X}{p}\right)^2\right)^{\frac{1}{2}}}\right\}^{\frac{1}{2}} \quad \ldots\ldots\ldots (16)$$



Values for helium: Table XV of Compton's paper (loc. cit. page 208) gives the kinetic theory values of the mean free paths of electrons and molecules in various gases. From it we find λ_2 for helium $= 0{\cdot}02035$ cm., and since for helium $m = 6{\cdot}59 \times 10^{-24}$ gm., we have for helium ions in helium at 20° C. and normal pressure

$$k = 94.4 \left[1 + \left(1 + 1.98 \frac{X^2}{p^2} \right)^{1/2} \right]^{-1/2} \left[1 + \frac{2}{1 + \left(1 + 1.98 \frac{X^2}{p^2} \right)^{1/2}} \right]^{1/2}$$

The values of k calculated for values of X/p between 0 and 10 are shown by Graph I (Fig. I). It will be observed that the value of X/p has marked effect on the mobility. In this figure there are shown for comparison the values 26.5 calculated by Hassé (16), and 21.4 obtained experimentally by Tyndall and Powell for values of X/p between 0.3 and 4.2. It is of interest to calculate the kinetic theory value of σ^2 corresponding to the value of λ_2 used above.

Since

$$\sigma^2 = \frac{1}{\sqrt{2}\,\pi N \lambda_1} = \frac{760}{\sqrt{2}\,\pi N \lambda_2} = 3{\cdot}11 \times 10^{-16} \text{ cm.}^2 \text{ at } 0^\circ \text{ C.}$$

therefore diameter of helium molecule $\sigma = 1{\cdot}76 \times 10^{-8}$ cm. This value is much less than that quoted by J. H. Jeans *(Dynamical Theory of Gases,* 3rd edition, page 288) which is $\sigma = 2{\cdot}18 \times 10^{-8}$ cm. This latter value is calculated from the coefficient of viscosity. From Langevin's theory it is easy to calculate the mobility at 20° C. in the following cases:

(1) small attractive forces $\lambda A = \frac{3}{4}$, and $k = 54{\cdot}3$.

(2) attractive forces more important than collisions, $A = 0{\cdot}505$ and $k = 22{\cdot}8$.

(3) assuming $\sigma = 2{\cdot}18 \times 10^{-8}$ cm., then $\lambda = 0{\cdot}622$, and $A = 0{\cdot}590$, and $k = 26.5$.

For small electric fields Compton's equation gives $k = 61.3$. The ratio between this and Langevin's value 54.3 is 1.13. The ratio between the numerical constants 0.921/0.815 is also 1.13, which therefore completely accounts for the difference in values. The effect of neglecting the attractions is to increase the value of k by over 100%.

Values for Hydrogen: From Eq. (16), using the value $\lambda_2 = 0{\cdot}01322$ cm. given by Compton, the values of k shown in Table I have been calculated. This kinetic theory value of λ_2 corresponds to $\sigma^2 = 4{\cdot}78 \times 10^{-16}$ and $\sigma = 2{\cdot}19 \times 10^{-8}$, whereas the value given by Jeans is $\sigma = 2{\cdot}71 \times 10^{-8}$.

TABLE I.—Mobilities of positive ions in hydrogen at 20° C. and 76 cms. pressure.

X/p	0	0·1	1	4	10
k	86·4	86·3	76·5	47·0	32·8

In this gas the value calculated from Langevin's theory is 19·0, whereas if the attractions are neglected it becomes 49·9. Hence the attractions between ions and molecules account for a factor 2·62, which is greater than in the case of helium (2·05).

Values for positive ions in various gases: Using Langevin's Eq. (2) values have been calculated for the mobilities of positive ions at 20° C. and normal pressure using the values for molecular diameters given by Jeans (loc. cit.). The following estimated values of σ which are not given by Jeans were employed.

TABLE II.

Nature of Particle.	+ Hydrogen (atomic).	+ Mercury.	+ Sodium.	Neon.	Argon.
$\sigma \times 10^8$ in cms.	0	4·40	2·76	2·76	3·68

The quantities required in the mobility calculations are the density and dielectric constant of the gas; the masses of the ion and the molecule; and the radii of the ion and the molecule, the sum of whose values is assumed to equal σ. The statical values of the dielectric constants given by Hassé (loc. cit. Table IV) have been used. These are in fair agreement with the more recent values measured by Watson, Rao, and Ramaswamy (19). The mobilities for monomolecular ions moving in their own gas have been previously calculated by Hassé (16), and the mobilities for the positive clustered ions have been taken from his paper. These ions were assumed to have a layer of twelve gas molecules round the parent positive ion. In some cases it has not been possible to compare the calculated mobilities with recent experiments where a high degree of purity has been attained in the gases, in which case no experimental value is shown in Table III.

TABLE III.—Mobilities of Positive Ions in Pure Gases.

Type of Ion.	Gas.	Mobility at 20° C. and normal pressure.			
		Calculated.	Experimental.	Observer.	Reference Number.
Helium	Helium	26.5	21.4	Tyndall & Powell	8
Mercury	„	14.7	11.8 12.2	„ „	14, 8
Sodium	„	20.1	23.1	„ „	13
Sodium	Neon	8.46	8.87	„ „	13
Sodium	Argon	3.46	3.21	„ „	13
Hydrogen (molecular)	Hydrogen	19.1	—		
Hydrogen (atomic)	„	21.8	—		
Sodium	„	14.1	18.1	Loeb	10
Sodium + water molecule	„	13.7	14.0 (13.6)	„ Bradbury	10 3
Clustered-ion	„	8.5	8.7 8.5	Loeb Bradbury	10 3
Nitrogen (molecular)	Nitrogen	3.46	—		
Sodium	„	3.64	3.78	Loeb	10
Sodium + water molecule	„	2.96	3.10	„	10
Clustered-ion	„	1.41	1.65	„	10

It will be observed that if a correction factor of about 1.05 is applied to the calculated values to allow for the Chapman-Enskog correction the agreement with the experimental results will be improved in all cases except for sodium ions in argon, and for helium ions and mercury ions in helium. An explanation of the high calculated values for these two ions in helium is given in the discussion.

5.—Discussion:

Immediate consequences from the calculations and comparisons made are:—

(1) Mobilities calculated from Langevin's general equation are much closer to the experimental results than those calculated from Compton's equation.

(2) In the gases considered the effect of neglecting the attractive forces between ions and molecules, as is done in Compton's equation and in Langevin's simplified equation, is to obtain mobilities much higher than the experimental values.

(3) There is a sufficiently close agreement between the recent experimental results for mobilities of positive ions in pure gases and the predictions from Langevin's theory to quicken scientific interest in the mechanism of collisions between ions and molecules.

(4) As there is practically no experimental evidence that the mobility of positive ions depends on X/p, the terms in Compton's equation expressing this dependence are unnecessary, except possibly when X/p is large.

If we consider only small values of X/p which appertain in all mobility experiments, Compton's Eq. (13) becomes

$$k = \frac{0.921\, e\, \lambda_0}{(2\, e\, \Omega\, M)^{\frac{1}{2}}} \times \left(1 + \frac{M}{m}\right)^{\frac{1}{2}}$$

which is identical except for the numerical constant with Langevin's Eq. (11), in which the effect of the attractions has been ignored. Compton (17) has pointed out that his mobility equation, which has no arbitrarily adjustable constant, is probably more correct than Langevin's Eq. (11), and we will see in considering the motion of electrons that there is evidence in support of this contention. But, in the case of ions, it is clearly less correct than Langevin's general Eq. (2), which also contains no arbitrarily adjustable constant, and in addition leads to the well-established law connecting mobility and pressure, and to the fact that the mobility is independent of the electric field for small to moderate fields. Compton states his reasons for neglecting the attractive forces in the consideration of electrical discharges in gases, but these reasons are unsound when applied to mobility work. He writes for the law of force between the ion and neutral molecule (loc. cit., page 209)

$$F = \frac{D - 1}{4\,\pi\, N} \times \frac{e^2}{\sigma^5} = B\,\sigma^{-5}\ ,$$

whereas the correct form (Eq. (1)) is double this. This attraction both increases the number of times that the centre of an ion comes within the distance σ of the centre of a molecule, and also deflects the path of the ion when ion and molecule pass near each other, but not near enough to collide. Each of these effects reduces the diffusion and the mobility of the ion. Since the diffusion constant d and reduced mobility K (i.e., the mobility at 0° C. and normal pressure) are proportional to the mean free path in the absence of attraction, Compton uses their reduction to define the mean free path in the presence of attraction. So $\lambda_1'/\lambda_1 = K'/K = d'/d$ where the primed symbols represent the values in the presence of attraction. Langevin has calculated K and d for elastic spheres both with and without attraction when the ions and molecules are in thermal equilibrium, and hence have the same average kinetic energy E. The effect of attraction depends on the ratio $\frac{1}{4} B/(E \sigma^4)$ where $\frac{1}{4} B/\sigma^4 =$ work to separate an ion and molecule from centres distant σ to infinity against the attractive force, so that it equals the energy of dissociation of an elementary cluster. Compton gives values for this ratio and for λ_1'/λ_1 which presumably are taken from Langevin and Hassé's papers to which references are made. These values are shown in Column I (Table IV). In making his estimates a numerical error of considerable size has been made which may have influenced Compton in his judgment of the relative unimportance of the attractive forces. The correct values obtained by Langevin and Hassé are shown in Column II. If the mean free paths are defined by energy loss the effect of the attractions is found by Sir J. J. Thomson (*Conduction of Electricity Through Gases* 3rd edition, page 51) to be rather greater (see Column III).

TABLE IV.

$\frac{1}{4} B/(E \sigma^4)$	Values of $\lambda_1'/\lambda_1 = K'/K = d'/d$		
	I (Compton).	II (Langevin & Hassé).	III (Thomson).
∞	0	0	0
10	.076	.197	.07
5	.15	.28	.10
2.5	.31	.40	.14
1	.73	.63	—
0.5	.93	.79	—
0.3	.97	.88	—
0	1.00	1.00	—

We are mainly concernéd with the value of $\frac{1}{4} B/(E \sigma^4)$ for which there is an appreciable change in the mobility due to the attractions. To produce a 20% reduction in the mobility $\frac{1}{4} B/(E \sigma^4)$ must equal about 0.9 according to Compton, and 0.5 according to Langevin and Hassé, so Compton has definitely underestimated the effect of the attractive forces. From his figures Compton concludes that " the ion free path is not appreciably diminished by the fact of its charge unless the mutual kinetic energy is of the order of the cluster dissociation energy, or less." Since this conclusion is sufficiently vague it cannot be called wrong, but the corrected figures show that if the mutual kinetic energy equals the cluster dissociation energy the mobility is reduced by 37%, which is a considerable effect. Further, Thomson (loc. cit.) draws a different conclusion to

Compton from his approximate investigation, viz., "for the mobility of the charged ion to be much reduced, the clustered dissociation energy must be considerable compared with the average kinetic energy of a molecule." This is the condition that aggregates of charged and uncharged molecules should be formed, so that it follows that if the mobilities of the ions are much reduced by their charges then clusters will form, and when no clusters form the mobility will not be greatly reduced. Compton concludes that this phenomenon will play no appreciable rôle in ordinary vacuum discharge tubes or any discharges which dissipate large amounts of energy. These are not the conditions under which mobilities are experimentally determined, so this phenomenon may be important in such cases of feeble electrical conduction through a gas at considerable pressure. It is interesting to note that Tyndall and Powell (8) found no evidence of ionic clusters in their work on pure helium. From the shape of their curves they are able to say with confidence that they dealt with positive ions of helium, unaffected by impurity. Yet even in this case of complete absence of clusters the effect of the attractive forces reduces the mobility by about 50%. The method adopted for allowing for the attractive forces is only a first approximation, but it is not possible to make a much closer approximation until more knowledge is obtained about the nature of the forces between ions and molecules when they are in close proximity. Debye (21) has shown that an inverse fifth-power law of attraction would hold whether the polarization of the molecule were due to a dielectric displacement or the orientation of a permanently dipolar molecule in the field of the ion. Loeb's (10) contention—that the law of force has been deduced from ordinary forces of dielectric polarization in weak homogeneous fields, and it is improbable that this would prove accurate for the huge inhomogeneous fields existing within a molecular diameter or two of an ion—appears reasonable, but the inaccuracy caused is probably small.

One of the greatest sources of inaccuracy in the use of Langevin's general equation is in the value of σ. Eq. (3) shows that σ^2 is required to obtain λ, from which A is derived. It is true that the values of A (and so of the mobility) are not very sensitive to changes in λ: nevertheless such crude approximations are made in arriving at σ and such large differences exist in the values of molecular and ionic diameters obtained by various methods (see Loeb *Kinetic Theory of Gases*, Appendix I) that this is an important source of error. The value of σ is assumed to be the sum of the radii of the molecule and the ion. The method of Hassé (10), which has been adopted in this paper, is to take the effect of the attractive and repulsive forces of the neutral molecule as equivalent to that given by an elastic sphere whose radius can be determined from measurements of viscosity. Hassé states that this assumption is very unsatisfactory, and so is the second assumption that the effect of the attractive force between the ion and the neutral molecule calculated from Eq. (1) can be superposed on that due to the attractive and repulsive forces of the molecule itself. These assumptions cannot be very far from the truth, and they give a simple method of treating the problem, so it is justifiable to adopt them until there is a definite advance in the state of our knowledge. A minor difficulty is that the temperature variation of the molecular radii is uncertain, but fortunately it is small over the range 0° to 20° C. Attention should be drawn to the fact that the values of the molecular radii given by Jeans (loc. cit.) have been calculated from viscosity determinations by a formula due to Chapman, and that this formula yields values considerably greater than some other methods. Chapman (22) has corrected the usual kinetic theory expression for the coefficient of viscosity $(\frac{1}{3}\, m\, C')/(\sqrt{2}\, \pi\, \sigma^2)$, where C' is the mean velocity of the molecules, and obtains the expression $0.499\, m\, C'/(\sqrt{2}\, \pi\, \sigma^2)$, by using for the molecular mean free path of molecules an expression $1{\cdot}5/(\sqrt{2}\, \pi\, N\, \sigma^2)$, instead of the usual kinetic theory value $1/(\sqrt{2}\, \pi\, N\, \sigma^2)$. Chapman also calculates the molecular diameters from the constant b of Van der Waals' law, and obtains values in close agreement with those calculated from viscosity data, using the rigid methods he applies to the kinetic theory. It is probably due to a considerable difference in the values he adopts for σ, that Loeb's calculations (10) from Langevin's theory for the mobilities of positive sodium ions in hydrogen and nitrogen are much lower than those we have calculated (Table III).

Kallmann and Rosen (23) discovered that the probability of charge transfer is very great for gas ions moving in a gas of their own molecular or atomic species. This experimental fact is well established, and has been utilised by Beeck (24) to produce beams of neutral argon atoms, and to explain the results found in the ionization of inert gases by slow alkali molecules. We have seen that there is strong experimental evidence (Tyndall and Powell (8), (9), and (14); and Zeleny (12)) that the phenomenon of charge transfer plays an important rôle in some ionic mobility determinations both on account of the probability of an ion capturing an electron from one of its own atoms, and also the possibility that it will transfer its charge similarly in an encounter with an impurity molecule. If the ionization potential of the impurity molecule is less than that of the gas atom, the impurity ion so formed will not lose its charge in collisions with other gas atoms, and therefore a very small concentration of impurity is sufficient to change completely the average mobility rate. This phenomenon of electron capture is likely to prove of great importance. In the case of a gas like helium with a high ionization potential it affords a method of determining the mobility of positive ions of other gases present in minute quantities, and if the gases are present in known concentrations it may be possible to determine the target area for electron capture presented by their molecules to helium ions at very slow speed (see Tyndall and Powell (14)). It was because the ionization potentials of the alkali metals are far below those of any common gaseous molecules or organic impurities that Loeb (10) suggested using them for mobility determinations. Hassé and Cook (25) have calculated the effect on the mobility of positive ions of the transference of charge from the ions to their own atoms. In all cases this results in a decrease of mobility, and the decrease depends on the importance of the attractive force between ion and atom, being negligible for a small attractive force. In the case of helium ions in pure helium where the probability of transference is high, it is reasonable to assume that about half the encounters result in a transfer. On this basis Hassé and Cook calculate from the Langevin theory that the mobility is 21.2, instead of 26.5 for no transference. The most accurate experimental value is 21.4. Since calculation shows that the ratio of the mobility of the mercury positive ion to the helium ion is 0.555, the mobility of the mercury ion becomes 11.8 on the basis helium 21.2. This is in close agreement with recent experimental values (see Table III). The only other large discrepancy between the calculated and experimental mobilities in Table III is the case of sodium ions in hydrogen where the values are 14.1 and 18.1 respectively. In this case it is just possible on account of the high temperature of the Kunsman source that the short-lived fast ions which Loeb measured were hydrogen ions and not sodium ions, so that their velocity would be expected to be somewhat less than 19.1 on account electron transfers.

The best experimental results for ions point to the following relations for the mobility k:—

(1) k is independent of X.

(2) k is inversely proportional to p.

(3) k proportional to T if the pressure is constant. These three relations hold over large ranges.

(4) k depends on the mass of the ions and of the molecules through which they move.

(5) k depends on the nature of the charge in the case of normal ions.

The bearing of the mobility equations on (1) and (2) have been discussed. The temperature effect on k is still uncertain according to Loeb (20). Langevin's theory shows that k (at constant pressure) is a function of the temperature, and the form of the function depends on the assumptions made regarding the actions between ions and molecules.

(1) If they are regarded as elastic spheres whose size and mass are independent of the temperature, then $k \propto T^{\frac{1}{2}}$. Compton's equation leads to the same result.

(2) If account is taken of the effect of attractions in increasing the number of collisions, then Langevin's theory leads to the relation k' (at constant density) $\propto T^{\frac{1}{2}}/(C + T)$.
This is the relation suggested by Sutherland (27), and is in fair agreement with the experiments of Phillips.

(3) If the actions are like those between centres of force varying inversely as the $(n + 1)^{\text{th}}$ power of the distance, then Langevin's theory leads to the relation $k' \propto T^{(2/n - \frac{1}{2})}$. This will be in best agreement with experiment if $2/n - \frac{1}{2} = 0$, i.e., $n = 4$. So an inverse fifth power law of attraction, which has been assumed throughout, gives good agreement

for the temperature effect. Compton's equation, which makes no allowance for the attractions, does not give the correct temperature variation.

It was believed until a few years ago that the mobility of ions was independent of their mass, but recent experiments have disproved this. Langevin's, Compton's, and other mobility equations include a mass factor $(1 + m/M)^{\frac{1}{2}}$ which can assume the limiting values 1.41 for monomolecular ions and 1 for very heavy ions. As this difference was inconsistent with the experimental evidence then available, some physicists concluded that the ions if monomolecular cannot remain unaltered during their path through the gas, but go through various phases in which they have different mobilities, and that the mobility measured by the usual methods is an average, and not its value in any particular phase. In view of later experiments the reason for this conclusion is removed, but it should be noted that the influence of different phases is clearly shown by the carriers of negative electricity—the negative ion and electron. The most accurate measurements illustrating the effect of ionic mass are those of Tyndall and Powell (13), (14). These experimenters found that the ratio of the mobility of the mercury to the helium positive ion in pure helium was 0.55. If we adopt the value $2{\cdot}20 \times 10^{-8}$ cm. for the radius of the mercury ion, the calculated ratio between these mobilities is, on Langevin's theory, $\frac{A_1\ (1 + 4/200.6)^{\frac{1}{2}}}{A_2\ (1 + 1)^{\frac{1}{2}}} = \frac{0{\cdot}458}{0{\cdot}590} \times ({\cdot}51)^{\frac{1}{2}} = 0.555$, which is in very close agreement with the experimental value. These experimenters also showed that in the case of argon the fall in mobility of the positive alkali ions from sodium to caesium closely follows the $(1 + m/M)^{\frac{1}{2}}$ relation, but that in the case of neon, and still more so in the case of helium, the fall in mobility with increase in mass is greater than that given by this expression. This can be accounted for by the decreasing polarizability $(\propto (D - 1))$ of argon, neon, and helium, which are related as 8 : 2 : 1. With a gas of low polarizability the size of the elastic spheres cannot be neglected, and the increase in size of the ions from sodium to caesium produce a decrease in A, which reduces the mobility, in addition to the reduction due to the increased mass of the ion. It is clear that relative values of the mobilities can be estimated from the theory with a higher degree of accuracy than absolute values.

In the lighter gases the mobility of the normal negative ions is greater than that of the positive. Hassé (16) explains the difference on the assumption that the negative ion has a layer of molecules about an electron, whereas the positive ion has a single layer of twelve molecules about a charged molecule. The values he obtained are of the right order, but the electron attachment results of V. A. Bailey and of Loeb speak against it, besides which Loeb (26) and Luhr (28) have found experimental evidence to show that the normal ion has only one or two molecular additions which are the result of electrochemical forces depending on the molecular constitution and the sign of the charge. Loeb tries to account qualitatively for the mobility difference by ascribing it to the specific electrochemical combinations which result by reaction of positive and negative ions with various molecular impurities or ionization products present in some gases. Reliable experiments indicate that there is a spectrum or range of mobility among the normal positive and negative ions in air of ages from about 0.5 to 2.0 seconds (see Loeb and Bradbury (26)). This is probably due to the difference in mass and diameter caused by the one or two electrochemically bound addition molecules.

6.—Conclusions:

Though the mobility of gaseous ions has been the subject of numerous investigations during this century, there are still many aspects of the subject which require explanation. The recent experiments on positive ions in pure gases should give a marked impetus to this study. The experimental results obtained are much higher than previous ones, and are in good general agreement with mobilities calculated from Langevin's theory. For ions, Langevin's general equation is definitely superior to Compton's equation, which is inaccurate, as no allowance is made for the effect of the attractive forces. Until the new quantum mechanics yields a more detailed knowledge of the mechanism of ionic encounters, it is likely that little progress will be made beyond the theory of ionic mobility advanced by Langevin and somewhat modified by Hassé.

PART II.—MOBILITIES OF ELECTRONS IN PURE GASES.

1.—Mobility Equations for Electrons:

The mean velocity *(W)* of an electron in the direction of a uniform electric field *(X)* is under some conditions not proportional to X, so that the term mobility has, under these circumstances, no definite meaning [vide V. A. Bailey, *Phil. Mag.* 46, 213, 1923].

Although the extension of the concept of mobility to the motion of electrons really serves no useful purpose, K. T. Compton has found it convenient to evaluate the velocity of an electron in the direction of the electric field as if it had a mobility [$= W/X$], and to study the deviations from this in terms of an interpretation from the kinetic theory. In order to avoid confusion, the terms used by Compton have not been altered in the discussion of his work in this section, except in the case of the so-called " mobility constant " for which the more rational term—reduced mobility—has been used.

The application of the kinetic theory to the motion of electrons in gases was first suggested by Townsend (29), and has been considerably amplified by K. T. Compton. Owing to their exceedingly small mass compared with ions, electrons will have mobilities thousands of times greater than ions. For ions the mobility varies inversely as the pressure over a large pressure range, i.e., the product pk is a constant. Lattey (30) found an abnormal increase in this product in the case of negative ions in carefully dried air at pressures less than atmospheric and considerably higher than those for which the increase normally began. This may be explained by supposing that at low pressures the negative ion is an electron for part of its life. At these pressures the mobility depends on the electric field. Further, the mobility of electrons will depend on the velocity they possess before the field is applied. If this velocity is not that corresponding to the energy due to thermal agitation—and in the case of electrons the attainment of this value is a slow process, while the chance of attachment to a molecule is in some gases appreciable—then the ordinary expression for its mobility will not apply. The mean free path of an electron, due to its much higher velocity, does not appear to be reduced by the presence of its charge. These considerations and others of a similar nature require that the mobilities of electrons should be treated independently to a large extent from those of ions.

From Eq. (11), which was deduced by Langevin from the elastic collision theory when the influence of the charges was neglected, we deduce for electrons, since $M \ll m$, and λ_0 = electron mean free path, $k = 0{\cdot}815 e\, \lambda_0/MC$.

Since $E_1 \geqslant E_2$, Eq. (10) similarly gives

$$k = [0{\cdot}921 e\, \lambda_0]/MC \quad \dotfill (17)$$

Now according to Pidduck's calculations ⁽³¹⁾, the numerical constant in the case of electrons moving under a uniform electric force is about 0.92, which is in much closer agreement with Compton's constant (0.921) than with Langevin's. These simple equations, which include no term depending on the field strength, can only be expected to give the order of magnitude of electronic mobilities. Compton's Eq. (15) would be expected to give a greater approach to accuracy. If X is small it simplifies to $k = (0.921 e\, \lambda_0)/(2e\, \Omega\, M)^{\frac{1}{2}}$, and this is identical with Eq. (17) only when $E_1 = E_2$, which is not in general true. If K represents the reduced mobility, i.e., the mobility under standard conditions, then

$$K = \frac{W}{X} \times \frac{p}{760} \times \frac{273}{T} = k \times \frac{p}{760} \times \frac{273}{T} \quad \dotfill (18)$$

where k is the mobility at pressure p mm. of mercury and absolute temperature T. K is often called the mobility constant, but this term is misleading. By Eq. (18), Compton's Eq. (15) can be reduced to a more convenient form for application to particular cases. Let λ = electron mean free path at 0° C. and 1 mm. pressure, then

$$\lambda_0 = \frac{\lambda}{p} \times \frac{T}{273} \quad \dotfill (19)$$

If E_0 = kinetic energy of a gas molecule at 0° C., then $E_2 = E_0 T/273$. Let M = molecular mass on the basis mass of the hydrogen atom = 1, then we have on substituting from Eqs. (15) and (19) in Eq. (18) and then inserting the values of known constants

$$K = 271000\, \lambda\, (273/T)^{\frac{1}{2}} \left\{ 1 + \left(1 + 1{\cdot}106.10^{6}\, M\, \lambda^{2}\, (X/p)^{2} \right)^{\frac{1}{2}} \right\}^{-\frac{1}{2}} \quad \dotfill (20)$$

This is the equation Compton uses (loc. cit., page 234) in comparing his theory with the experimental results.

2.—The Transference of Energy in Collisions between Electrons and Molecules:

It is not proposed in this paper to attempt a detailed discussion of this complicated and at present unsolved problem, but merely to point out some salient features which will be of assistance in attempting to interpret the experimental facts. In the initial stages of the motion of electrons which start with a small velocity, the kinetic energy of the electrons increases as they move in the direction of the electric force; and since the direction of motion is changed in the collision with molecules of gas, the kinetic energy of the electrons appears as energy of agitation. After moving some distance in the direction of the force, a steady state of motion is attained where the electrons lose energy in collisions with molecules at the rate at which they acquire energy by moving in the direction of the force. The root mean square velocity of agitation *(C)* is then constant, and Townsend first pointed out that, in this steady state of motion, the energy of agitation of an electron may be much greater than that of a molecule of the gas. This property of the electrons has been proved experimentally(32). Let $E_1 = \frac{1}{2} MC^2 = eU$ represent the mean energy of agitation of an electron, and $E_2 = \frac{1}{2} mC_1^2 = e\Omega'$ represent the energy of agitation of a gas molecule at 15° C.; then the former may be expressed in terms of the latter by the relation $MC^2 = k_1 mC_1^2$, where C_1 = root mean square velocity of a gas molecule at 15° C., and $k_1 \geqslant 1$. When the electron gains its terminal velocity in the field, its terminal energy is often much higher than the energy of the gas molecules, and if the field is removed it loses this gradually, eventually attaining equipartition.

Physicists have adopted different viewpoints in considering the average fraction *(f)* of an electron's energy which is lost at an impact with a molecule and the influence that these losses have on the electrical properties of the gas. The method adopted by Townsend and his school, which has proved adequate to account for the large array of experimental results they have now collected, is described by Townsend in *Motions of Electrons in Gases* (Clarendon Press, Oxford, 1925). A summary of the experimental results obtained at the Electrical Laboratory, Oxford, is also given in this pamphlet. In a paper on *The Transference of Energy in Collisions between Electrons and Molecules*(33) Townsend and the writer criticised certain hypotheses relating to the transference of energy from electrons to molecules which some physicists had said were required by the (old) quantum theory. The conditions in mobility experiments are somewhat simplified, since the values of X/p are usually small, so that the electrons only lose a small fraction of their energy in collisions with molecules. Townsend defines the mean free path of an electron as the average distance an electron moves in a given direction with the velocity C before all directions of motion become equally probable, when the electric force is zero. He assumes that the average energy lost in a collision is equal to the average increase of energy of an electron in traversing a free path in the direction of the field. Then in the simple case where all the free paths are taken equal to the mean free path and the velocity of agitation is constant, the proportion of its energy an electron loses in a collision *(f)* is $4W^2/C^2$. When the distribution of the free paths about their mean, and the distribution of the velocities of agitation about their mean value are taken into consideration a different value is obtained for the numerical factor in the expression for *f*. Langevin assumed that the velocities of agitation were distributed according to Maxwell's law, and arrived at the numerical constant 0.815 in the mobility formula. This gives

$$f = 2.46\ W^2/C^2 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

Pidduck (loc. cit.) found that the distribution of the velocities of electrons is represented more accurately by a law given by Lorentz than by Maxwell's law. This led to a constant 0.92 in the mobility equation, which is very close to Compton's value and leads to

$$f = 2.17\ W^2/C^2 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

Eq. (21) has been criticised by Compton, Loeb, and others, but it has been useful in explaining the experimental results obtained by Townsend and his collaborators, who have found no adequate reason for discarding it, although it is clearly realised that the exact numerical coefficient is uncertain. In his discussion of this subject Loeb (*Kinetic Theory of Gases,* page 518) says that the reason why Townsend's simple relations so nearly fit the experimental facts is still a mystery. He admits that they are at least good approximations which will form the first and most important terms in more accurate and complicated equations based on a more detailed consideration of the factors concerned.

For a perfectly elastic collision between an electron and a stationary molecule

$$f = 2M/m \times \left(1 - \frac{\Omega}{U}\right) = 2M/m \times \left(1 - \frac{1}{k_1}\right) \ \ldots\ldots\ldots\ldots (23)$$

Eq. (23) is used by Compton in his earlier papers (34), but in his recent review (17) he uses the corrected form due to Cravath

$$f = 2.66M/m \times \left(1 - \frac{\Omega}{U}\right) = 2.66M/m \times \left(1 - \frac{1}{k_1}\right) \ \ldots\ldots (24)$$

in obtaining his mobility equation for electrons (Eq. 15)). If, in the derivation of Eq. (15), we do not substitute for f from Eq. (24), we arrive at an expression for electron mobility

$$k = 0.921e\ \lambda_0/MC = 0.775 \left(\frac{e\,\lambda_0}{M\,X}\right)^{\frac{1}{2}} \times f^{\frac{1}{4}}$$

Substitute for λ_0 from Eq. (19) and we get for the reduced mobility

$$K = k \times \frac{p}{760} \times \frac{273}{T} = 4{\cdot}16.10^4\ (p\ \lambda/X)^{\frac{1}{2}} \times f^{\frac{1}{4}} \ \ldots\ldots\ldots\ldots (25)$$

where it has been assumed that k is measured at 15° C. and pressure p mm. Eq. (25) can be used to calculate reduced mobilities of electrons for comparison with experimental results provided the appropriate value of f is substituted. Eq. (25) is identical with Eq. (20) when the value of f adopted by Compton is used. According to Compton, for electron speeds below a certain critical value determinable for each gas, the collisions with molecules are elastic, so Eq. (24) applies accurately. Townsend considers that Eq. (21) is the best expression to use for f, and the coefficient 2.46 is the most probable one. The values obtained experimentally for the losses of energy of electrons in collisions with atoms of monatomic gases at small values of X/p are nearly the same as calculated values for smooth elastic spheres. For larger values of X/p the losses are much greater, due to large losses of energy in some collisions, when ionization by collision becomes appreciable. With diatomic or polyatomic molecules the losses even with fairly small values of X/p are considerably greater than those calculated on the assumption of smooth elastic spheres. Townsend (35) has pointed out clearly that, when the collisions are taken as perfectly elastic and the spheres as smooth, his equation for f leads to approximately the same result as Compton's value. For this case Pidduck (31) found $k_1 - 1 = 1{\cdot}2\ W^2/C_1^2$ approximately, which gives

$$W^2/C^2 = \left\{\frac{1}{1.2}\right\}\left\{1 - \frac{1}{k_1}\right\}\frac{M}{m}.$$

Hence $$f = 2.46W^2/C^2 = 2\ M/m \times \left\{1 - \frac{1}{k_1}\right\}$$

approximately, in agreement with Eq. (23). So under these conditions Compton's and Townsend's methods will be in close agreement, but Townsend's value for f has a much wider range of application.

3.—Calculation of Electron Mobilities and Comparison with Experimental Results:

In 1923 Compton (34), using his mobility equation with constants slightly less accurate than used in Eq. (20), showed that the agreement with experiment was good in the case of hydrogen, and within a small factor in the case of helium, nitrogen, and argon for values of X/p less than the critical value which he specified as 20 for hydrogen, 1.3 for nitrogen, 0.5 for argon, and > 0.4 for helium. In this computation he used a fixed value for the electron mean free path which was calculated for each gas from the kinetic theory, and the experimental results were those of Townsend and Bailey, and of Loeb. In the case of oxygen the agreement was not good, indicating a very low critical value of X/p. Compton concluded that when electrons collide at speeds greater than that corresponding to the critical values of X/p, the collisions are no longer elastic as assumed in his theory. Deviations from the theory could possibly be accounted for in two ways:—

(1) The electronic mean free path may not be equal to that predicted from the kinetic theory.

(2) The electron impacts may not be perfectly elastic.

Compton showed that an increase in the value assumed for the free path increases the mobility more for small values of X/p than for large ones, thus leading to a steeper curve. On the other hand, an increase in the fractional energy loss at impacts tends to flatten the curve by increasing the mobility more for large values of X/p.

In a recent review (17) Compton uses his Eq. (20) to compare his theory with the best experimental results for hydrogen and for nitrogen. The same experimental results as were used in his earlier comparison were used for hydrogen, but in the case of nitrogen he used Wahlin's results (36) in place of Loeb's. For values of $X/p < 0{\cdot}1$ in nitrogen the theoretical curve lies well below the experimental, and as the hypothesis of inelastic collisions would not increase the mobility at $X/p = 0$, Compton can only suggest that the fact that scattered electrons are much more concentrated in the forward direction than would be true of elastic spheres would introduce a correction in the right direction. In hydrogen and helium, on the other hand, he finds that the theoretical curves are above the experimental ones. He suggests that this might be accounted for by using the experimentally determined mean free paths which are much smaller for these two gases than the kinetic theory values. This would overcorrect the discrepancy, so, in addition, he suggests it is again necessary to take account of the excess of scattering in the forward direction, which the quantum theory of scattering predicts is less pronounced at small, than at large, velocities. His general conclusion is that his theory gives results of the right order of magnitude and about the right type of variation of reduced mobility with X/p.

There appear to be simpler and more convincing methods of explaining the considerable variation between experimental results and those predicted by Compton's theory. Since 1923 more accurate experiments from which electron mobilities are obtainable have been performed on some gases. For these reasons the subject has been reexamined by considering the gases oxygen, nitrogen, and helium.

Of the six gases he studied, Compton found that oxygen departed furthest from his theory. The values obtained by Brose (37) with this gas have been used in place of Townsend and Bailey's earlier results as being probably more accurate, but the difference between them is small. Brose states that the number of ions in the streams of electrons he used was quite inappreciable even when comparatively large gas pressures were used. From the values of W listed by Brose, the reduced mobility K has been estimated at values of X/p up to 7 using Eq. (18). In making calculations from Compton's theory Eq. (25) has been used, after substituting for f from Eq. (24). This leads to the same result as using Eq. (20), but the calculation is much shorter. Except when $k_1 < 5$, the error is negligible for our purpose in writing $f = 2{\cdot}66\ M/m$, since it is $f^{\frac{1}{4}}$ which is used to calculate K. The maximum percentage error involved in this approximation is 5. We have also calculated the reduced mobilities from Eq. (25), using Townsend's value of f given by Eq. (21). In this case f is calculated from the experimentally determined values of W and C. It would be more consistent to use Eq. (22) for f in place of Eq. (21), since the same numerical coefficient (0.815) has been used in deducing Eqs. (22) and (25). This procedure would merely make the calculated values of K about 3% higher, so it is unimportant. We shall assume that λ remains constant over the range of X/p considered. λ is calculated from the kinetic theory value $= 4\sqrt{2} \times$ molecular mean free path. The molecular mean free paths are obtained from Compton's Table XV (loc. cit., page 208), which are the commonly accepted values. For oxygen $\lambda = 0{\cdot}0417$ cm., and $2{\cdot}66\ M/m = 0{\cdot}452 \times 10^{-4}$. Since for $X/p = 0{\cdot}4$, $k_1 = 6$, we can with sufficient accuracy write $1 - \frac{1}{k_1} = 1$ for all the values of X/p considered. The comparison is set out in Table V, and the curves showing the reduced mobility in oxygen as a function of X/p are shown in Fig. 2. The experimental mobilities are labelled Brose, and the calculated ones Compton and Townsend, depending on which expression for f was used in their calculation.

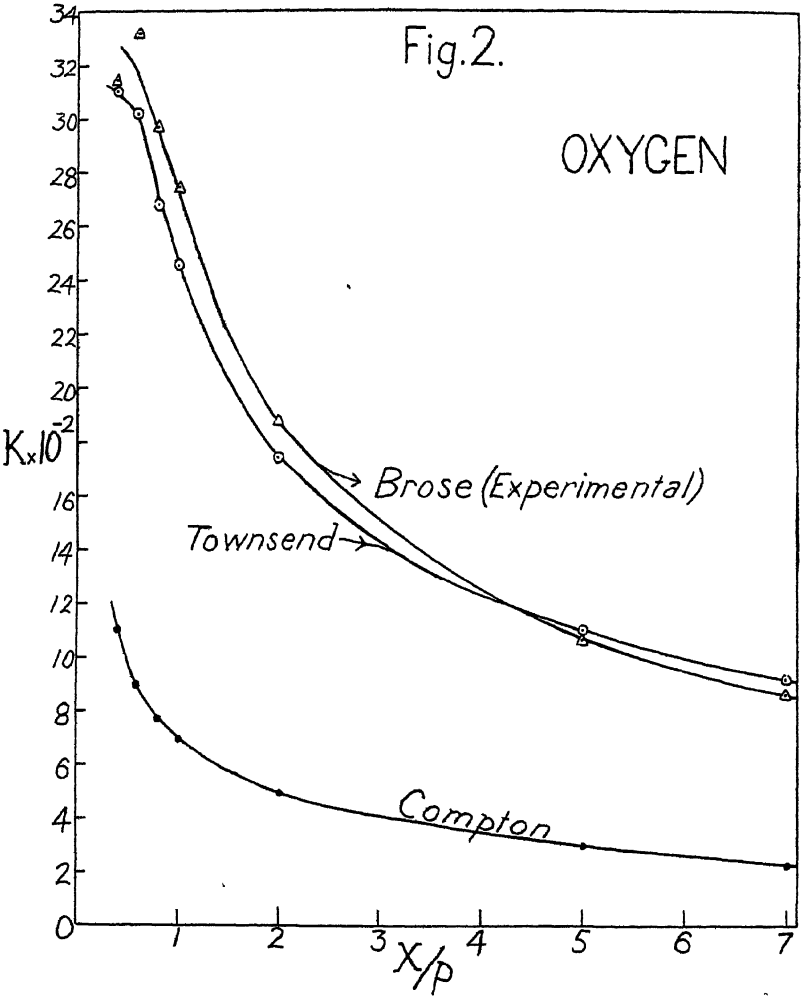


TABLE V.—Reduced Electron Mobilities in Oxygen.

X/p	$f \times 10^4$		Value of K			Difference %
	Compton.	Townsend	Brose	Townsend	Compton	Townsend/Brose
7	·452	83·0	884	935	262	+ 6
5	·452	73·0	1070	1110	312	+ 4
2	·452	69·8	1870	1740	494	— 7
1	·452	69·1	2740	2450	697	— 11
0·8	·452	62·6	2960	2670	779	— 10
0·6	·452	56·6	3320	3010	899	— 6
0·4	·452	27·5	3120	3090	1100	— 1

It is clear that in the case of oxygen the use of Townsend's expression for f is justified, and that for values of $X/p > 0{\cdot}4$ the collisions are not of the perfectly elastic kind.

In the case of nitrogen we employ the experimental results of Wahlin (86) for values of $X/p < 0{\cdot}1$ and those of Townsend and his collaborators for values of X/p from 0·25 to 2. These results lie well on a smooth curve although obtained by entirely different methods. It was not possible to calculate the values of f in the ordinary way from Wahlin's data. For comparison with Wahlin's results, therefore, mobilities were calculated by Compton's theory using Eq. (20). Then from these calculated values k_1, and hence f, could be calculated indirectly. The value of f obtained by Townsend's method was fairly constant between $X/p = 1$ and $X/p = 0{\cdot}25$, so this value for f was assumed to hold down to the lowest value of X/p (0·002). There is little justification for this assumption, so the figures dependent on it have been shown in brackets. For nitrogen $\lambda = 0{\cdot}0389$ cm., and $2{\cdot}66\ M/m = 0{\cdot}516 \times 10^{-4}$. Since for $X/p = 0{\cdot}25$, $k_1 = 7{\cdot}5$ we can use the approximation $1 - \dfrac{1}{k_1} = 1$ down to this value. The results of the comparison are shown in Table VI, and the corresponding curves are drawn in Fig. 3.

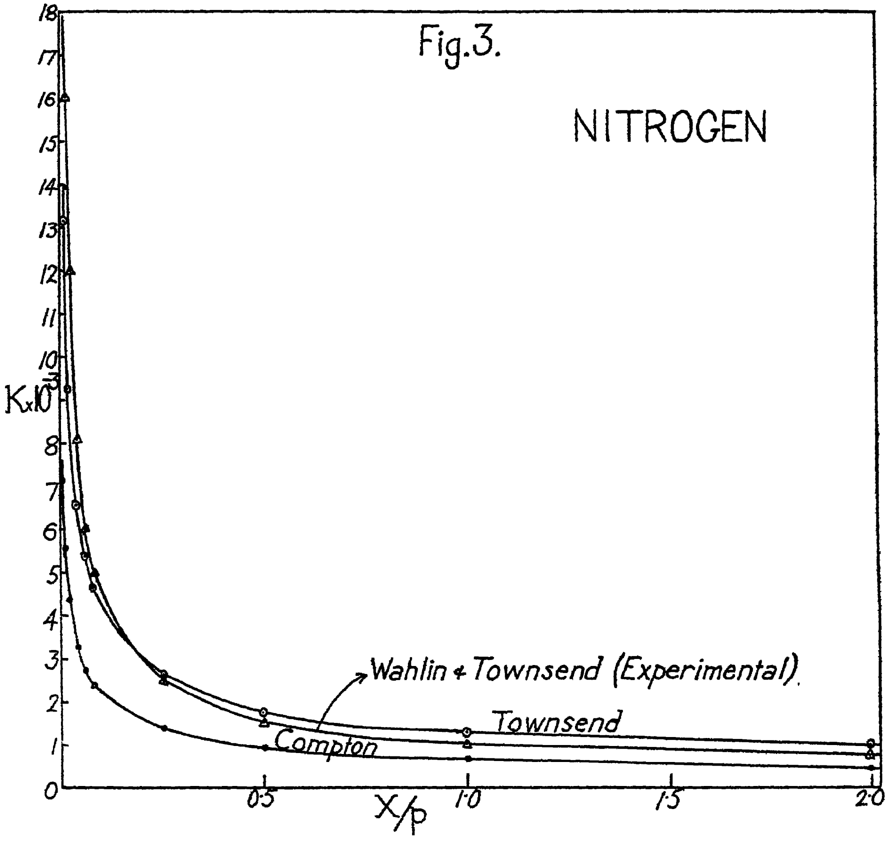


Fig. 3.

TABLE VI.—Reduced Electron Mobilities in Nitrogen.

X/p	$f \times 10^4$		Value of K		
	Townsend	Compton	Townsend & Wahlin	Townsend	Compton
2	·516	10·3	817	1035	493
1	·516	6·5	1080	1310	696
0·5	·516	5·5	1550	1770	976
0·25	·516	6·5	2570	2630	1390
0·08	·46	(6·5)	5000	(4640)	2390
0·06	·45	(6·5)	6000	(5350)	2740
0·04	·41	(6·5)	8050	(6550)	3280
0·02	·32	(6·5)	12000	(9250)	4380
0·01	·21	(6·5)	16000	(13100)	5570
0·002	·027	(6·5)	18000	(26800)	7080

According to Compton the critical value of X/p for this gas is about 1·3, so below this the collisions should be perfectly elastic. The curves show that this is only approximately true.

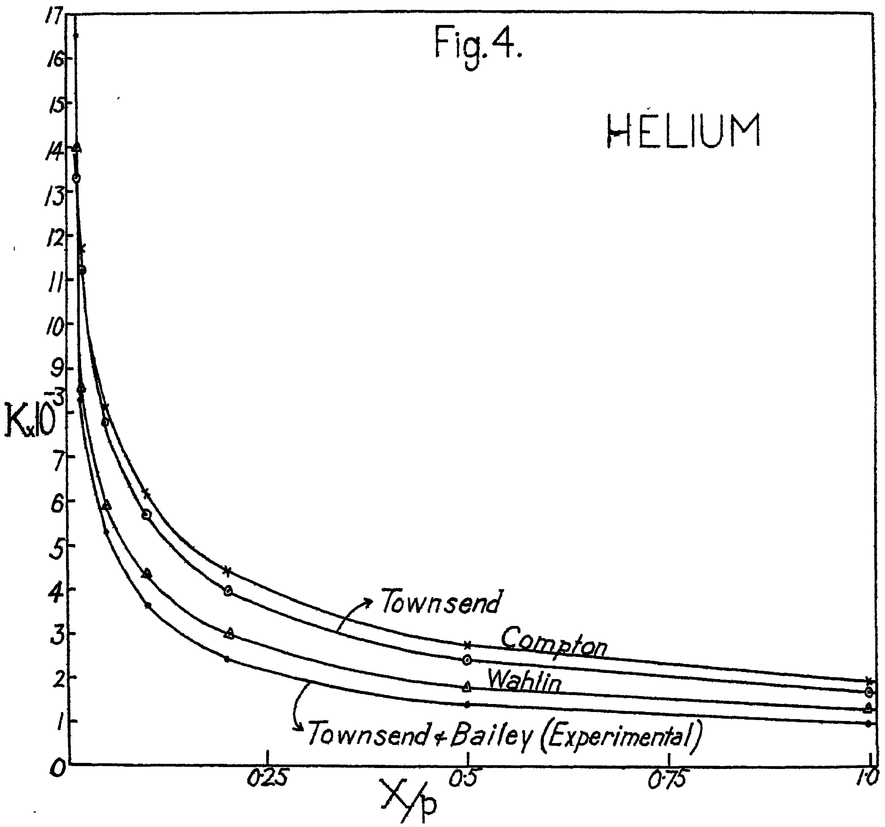


Fig. 4.

The experimental data referring to helium are those quoted in Townsend's pamphlet *Motion of Electrons in Gases* (page 590), and were determined by Townsend and Bailey. These are in close agreement with the results obtained by Loeb, which were used by Compton in his comparison. For helium $\lambda = 0{\cdot}115$ cm., and 2·66 M/m

$= 3{\cdot}62 \times 10^{-4}$. For $X/p = 0{\cdot}1$, $k_1 = 6{\cdot}2$, so we can use the approximation $1 - \frac{1}{k_1} = 1$ down to this value. The results of the comparison are set out in Table VII, and the corresponding curves are drawn in Fig. 4. According to Compton the critical value of X/p for this gas is $> 0{\cdot}4$, so below this the collisions should be perfectly elastic. We notice that for this gas Townsend's values of f are less than the value calculated on the assumption of perfectly elastic spheres. This is not unreasonable, for in some collisions the electrons gain energy from the molecules, so the mean loss per collision may be lower than the value calculated for a perfectly elastic collision.

TABLE VII.—Reduced Electron Mobilities in Helium.

X/p	$f \times 10^4$		Value of K		
	Compton	Townsend	Townsend & Bailey	Townsend	Compton
1	3.62	2·4	1030	1755	1960
0.5	3.62	2·3	1430	2450	2760
0.2	3.62	2·5	2450	3990	4380
0.1	3.62	2·6	3690	5700	6190
0.05	2·64	2·3	5350	7770	8050
0·02	1·91	1·56	8300	11200	11700
0·013	1·58	1·30	16500	13300	14000

4.—Discussion:

In all the gases considered, even when the values of X/p are less than the critical values specified by Compton, the mobilities calculated by the use of Townsend's expression for the average fractional energy loss at a collision are in better agreement with experiment than those calculated on the assumption of perfectly elastic collisions. In the case of helium, for values of $X/p < 1$, there is not much difference between mobilities calculated in these two ways, and in this gas the collisions are very nearly elastic for the small values of X/p. There is adequate evidence to show that the collisions between electrons and molecules are not perfectly elastic under the conditions which some physicists have assumed them to be. Throughout our calculations the electronic mean free path has been assumed a constant independent of X/p, and equal to the kinetic theory value. Even so the general agreement between theory and experiment has been good, especially when it is remembered that on account of experimental errors and various approximations which have been made an agreement of closer than 10 to 15% could not be expected. The agreement would be much better if we used other values for the mean free paths—a smaller value for helium, and higher values for oxygen and nitrogen. There is good experimental evidence to show that the mean free path of an electron is not always equal to the kinetic theory value and that it is a function of X/p. Townsend determines W and C by experiment for various values of X/p. He then calculates f from Eq. (21) and λ from the mobility equation

$$W = 0{\cdot}815 \times \frac{X}{p} \times \frac{e}{M} \times \frac{\lambda}{C}\ .$$

In this λ is the mean free path of an electron in the gas at 1 mm. pressure when the electrons are moving with the velocity *C*. The value of λ required to satisfy this equation is not the same for all values of *C*. This was the first suggestion that the mean free path of an electron depends on the velocity, and it was for many years viewed with suspicion, but has now been established by other experimental methods devised by Lenard (38), Ramsauer (39), and Langmuir and Jones (40). A comprehensive historical and critical account of this important work has been written by Brose and Saayman (41). These investigations point to a collision mechanism much more complicated than that assumed in the classical kinetic theory, and an allowance for the variation in λ from the kinetic theory value would improve the agreement in the case of those gases we have considered. Wahlin (42) from his experimental investigations finds the ratio between his observed values for the mean free path and the kinetic theory value for various gases. For nitrogen his figure is 2·53, and for helium 0·565. The adoption of these figures in our calculations would give a closer approximation to the experimental mobility values. In the case of helium, for the range of X/p considered, Townsend's mean value of λ agrees with Wahlin's value (0·066 cm.) and the adoption of this value in place of the one previously used (0·115 cm.) gives the curve labelled " Wahlin " in Fig. 4 for values calculated from Townsend's *f*. Loeb questions the measurements in oxygen on account of the relatively high probability of electron attachment, but this effect was not appreciable in Brose's experiments.

In a recent paper Massey (43) uses Born's method of applying the new quantum theory to the problem of the collision of electrons with rotating dipoles. He points out that the solution of the general case of collision at slow to moderate velocities of electrons with molecules is practically impossible, for the complete solution of the motion of an electron in the static field of the molecule would be required. He shows that if the rotator is initially in the ground state, then the probability of exciting the first rotational state is much greater than that of an elastic collision. If the rotator is not initially in the ground state, then the first rotational level will not, in general, be most strongly excited, but the probability of an inelastic collision will still be greater than that of an elastic one. The magnitude of these excitation probabilities is quite appreciable at low velocities, indicating that beams of slow electrons will exchange energy readily with dipolar molecules. The result of Massey's calculations is in general qualitative agreement with the experimental results of Townsend, Bailey, and others (44) on the loss of energy in collisions between slow electrons and molecules of polyatomic gases. These workers have shown that the losses in all the gases they have used, except helium, argon, and neon, are greater than can be explained by elastic collisions. The losses are greater in polyatomic gases than in monatomic ones. The support given to these experiments by Massey's calculations can only apply to those gases whose molecules have an electric moment, e.g., triatomic molecules and diatomic molecules having a slight dissymmetry.

In an interesting paper Bailey (45) has pointed out that the new quantum theory is in closer agreement with the experimental results obtained by Townsend and himself than was the old quantum theory, which some physicists believed conflicted with these experiments. For this purpose Bailey considered the absorption of light in the infra-red region and also the Raman effect in the scattering of light by the gases used. It was shown to be probable that with polyatomic molecules, the energy transferred from a slow electron to a molecule has a relation to the energy transferred from radiation to a molecule, whether in the process of absorption or of scattering.

5.—Conclusions:

Probably the best general mobility equation which has been proposed for electrons is that due to K. T. Compton. A modification of Compton's equation which improves its agreement with the experimental results is suggested. This is to adopt the expression for the average fractional energy loss at an encounter between an electron and a molecule proposed by Townsend, which implies that the collisions are not in general like those between perfectly elastic spheres, although in monatomic gases they are very nearly elastic for small values of X/p. No mobility equation which does not make allowance for the variation in electronic mean free path with variation in the mean velocity of agitation of the electron can hope closely to approach accuracy over a large range of conditions. There are indications that the new quantum theory will help to explain in greater detail the nature of the collisions between electrons and molecules at slow speeds, and so lead to advances in this subject.

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New Tertiary Mollusca from Timaru District, South Canterbury, New Zealand.

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[*Read before the Otago Institute, 11th November, 1931; received by Editor in revised form, 10th December, 1932; issued separately, June, 1933.*]

RECENT collecting has enabled the writer to add considerably to the faunal lists of one or two fossil localities in the district around Timaru. The most up-to-date lists available are those given in the *N.Z. Geological Survey Palaeontological Bulletin* No. 8 (1921). This Bulletin lists 32 species from the beds at Sutherlands, Tengawai River; but in an earlier list Gudex (*Trans. N.Z. Inst.*, vol. 50, pp. 244-62; 1918) gives 64 species of molluscs from that locality. In one day's collecting, however, the present writer succeeded in doubling the number of records from the outcrop at Sutherlands, bringing the number up to 121 species, which is in excess of that recorded from White Rock River.

The horizon is undoubtedly the same as that at White Rock River, not many miles distant, for the faunas of these two localities are almost identical. The state of preservation of the fossils at Sutherlands is, however, in marked contrast with that of the shells from the beds at White Rock River, at which locality it is rare to find a shell that has not been worn. Obviously the conditions of deposition differed at these two stations, sedimentation having proceeded a good deal more quietly at Sutherlands, while at the present White Rock River station the accumulating sediments must have been travelling under the impulse of a powerful current. Probably, then, the White Rock River fauna is not representative of the one, if any, that existed at that particular station, but is a record of molluscs that lived under more favourable conditions on some adjacent part of the ancient sea-floor, where the accumulating sediments were not being rapidly transported.

At Holme Station, near the lower end of Pareora Gorge, there is an outcrop along the hillside near the road, and in lithology and fauna the beds here are closely similar to those at Sutherlands, the brown sands again having interstratified bands of a calcareous nature. The beds are not as well exposed as those along the Tengawai, and a large collection was not attempted.

The brown sands with an Awamoan fauna outcrop also in bluffs on the left side of Opihi River, about three miles above its confluence with Tengawai River at Pleasant Point. The molluscs here are often rather decomposed, and the outcrop is not easy to collect from owing to deep, stagnant pools along one of the flood channels of the river close against the base of the cliffs.

The blue clays exposed on the left bank of Pareora River at the lower end of Pareora Gorge, about half a mile upstream from the outcrop of Awamoan beds at Holme Station, are the stratigraphic equivalent of the blue clays so well exposed along the Otaio River further south (Gudex, *Trans. N.Z. Inst.*, vol. 50, p. 244; 1918). Their fauna contains many Awamoan species, but the presence of such species as *Zexilia dalli* (Suter), *Globisinum crassiliratum* Finlay, *Austrofusus affiliatus* Finlay, *Parasyrinx subalta* (Marshall and Murdoch), *Poirieria primigena* Finlay, *Acuminia biplex* (Hutton), and a number of undescribed forms, points to a connection with the Hutchinsonian fauna at Otiake. This resemblance has already been remarked on by Thomson, from information furnished him by Finlay (*N.Z. Journ. Sc. and Techn.*, vol. 8, No. 3, p. 155; 1926).

The writer wishes to acknowledge his indebtedness to Dr H. J. Finlay for criticism and for the loan of material.

Genus CARDIUM Linné, 1758.

Type: *Cardium costatum* Linné.

Cardium gudexi n. sp. (Figs. 7, 14).

Shell large, of very heavy build, strongly inflated, considerably attenuated posteriorly. Anterior end evenly and broadly convex; posterior end narrowly rounded below, very lightly convex above; beaks almost at anterior fourth, incurved, flattened in the plane of the hinge, directed forward. Ventral margin very strongly dentate. Sculpture of 38 broad, flat radial ribs, separated over centre of valve by linear grooves; on posterior area ribs not so well defined and grooves a little more open. As a result of decortication towards the beaks the radials stand out clearly, separated by flat-floored grooves whose width is less than that of the ribs. The whole are crossed by a system of fine, slightly wavy striae, those in the grooves faintly convex ventrally; those on the ridges convex dorsally. Muscular impressions strongly incised, the posterior one the larger; pedal retractor scar separate, narrowly elongate dorso-ventrally. Hinge with two cardinal teeth, the dorsal one slightly anterior to beak; lower cardinal much larger, slightly behind beak, arising at edge of hinge-plate and elongated antero-dorsally. Cardinals separated by a channel opening into a very deep triangular pit anterior to lower cardinal. Anterior laterals separated by a broad, deep pit; lower one large and heavy, upper almost completely broken away. Posterior lateral tooth near remote end of hinge-plate; nymph broad and strong.

Height, 85 mm.; length, 96 mm.; thickness (one valve), 40 mm.

Locality: Sutherlands, Tengawai River, South Canterbury (Awamoan).

Type (a single right valve) in writer's collection.

This species is a near relative of *C. spatiosum* Hutton, with which it agrees very closely in shape of valve. The adult *spatiosum*, however, is more elongate, a good deal larger, and has tuberculate ribs and much wider grooves. *Gudexi* is obviously distinct from *C. strangi* Laws in shape of valve and in possessing much more massive hinge characters; the whole shell is of much heavier build than *strangi*, and has only 38 ribs as against 50.

Subgenus TRACHYCARDIUM Mörch, 1853.
Type: *Cardium isocardia* Linné.

Cardium (Trachycardium) cantuariense n. sp. (Figs. 1, 4, 5).

Shell large, well inflated, fragile; anterior end strongly convex above, rapidly retreating postero-ventrally below; posterior end descending almost straight. Whole dorsal margin straight and horizontal in one specimen; in another shell the anterior dorsal margin straight and gently descending. Beaks at middle, directed forwards a little, well incurved. Posterior margin arched outwards from plane of contact of valves (as in a specimen of *C. greyi* Hutton from Oneroa, Waiheke Island), so that valves appear to have been gaping. Sculpture of 62 low, flat radial ribs, separated by very narrow, almost linear grooves. On posterior part of valves the ribs are ill-formed, and it is the margin of this area that has been referred to above as being depressed below plane of contact of valves. Anterior, ventral, and posterior margins all dentate. Muscular impressions very weakly shown, posterior one large and circular, anterior one large and oval with its long axis vertical. Hinge very light, scarcely any differentiation into hinge-plate; teeth also small (for size of shell) and light of build. Right valve with two cardinal teeth, the lower one immediately below beak, high and conical, the upper cardinal a little in front of beak, oblique, low behind, and more elevated in front. The anterior side of the lower cardinal rises as a vertical wall bounding the very deep socket in which the main cardinal of left valve articulates. Left valve with large peg-like anterior cardinal; posterior dorsal cardinal broken away; the laterals distant from beak, elongated, light, narrow; posterior one arising from margin of valve, which is here not appreciably thickened into a hinge-plate.

Dimensions (the valves are not a pair); Right valve, height, 89 mm.; width, 101 mm.; thickness, 34 mm. Left valve (corresponding dimensions), 91 mm., 95 mm., 29 mm.

Locality: Sutherlands, Tengawai River, South Canterbury (Awamoan).

Types (odd right and left valves) in writer's collection.

This is no doubt the shell identified at the above locality as *C. greyi* Hutton (*N.Z. Geol. Surv. Pal. Bull.* No. 2, p. 56). It is not uncommon at Sutherlands, but it is difficult to collect. It is a close relation of *C. greyi*, but differs in having broader, lower, and flatter ribs with narrow interstices, which decrease in width ventrally and do not become wider as in *C. greyi.* The adult is smaller than that of Hutton's species, and the whole shell is a good deal less massive, the hinge and teeth being much lighter. The teeth, in fact, appear unduly small in contrast with the size of the valve. The species just described has been compared with a specimen of *C. greyi* from Oneroa, Waiheke Island, Auckland.

Genus Angulus Megerle, 1811.

Type: *Tellina lanceolata* Linné.

Subgenus Peronidia Dall, 1900.

Type: *Tellina albicans* Gmelin (*nitida* auct.).

Angulus (Peronidia) artus n. sp. (Figs. 11, 12, 13).

This is a very closely related ancestor of the Recent *A. edgari* (Iredale). It differs in having greater length relative to height, the posterior end being more produced and the postero-dorsal margin less rapidly descending; anterior end more narrowly rounded, and antero-dorsal margin a little straighter. The cardinal teeth of both species are the same, but the laterals are longer and more lamellar in the Miocene shell. The dorsal boundary of sinus arises at mid-anterior edge of posterior adductor, trends antero-dorsally about parallel with postero-dorsal margin of valve, and then suddenly bends around to run parallel with antero-dorsal margin of shell. The angle formed by change in direction of dorsal margin of sinus is high up and almost vertically beneath beaks in *A. edgari,* but lower, more obtuse and posterior to beaks in the new species. Fine internal radiations present in both species; in addition to these there are three low, wide, radial corrugations, seen only internally, and traversing a narrow zone of valve immediately anterior to the twisted posterior end. Left valve more convex than right valve. Sculpture of low, concentric ridges, closely packed together; towards posterior and over the angulation they become raised, narrow lamellae (seen only on a paratype).

Height (right valve), 16.5 mm.; length, 30 mm. Left valve (corresponding dimensions), 19.5 mm.; 34 mm.

Locality: Sutherlands, Tengawai River, South Canterbury (Awamoan).

Type and several paratypes in writer's collection.

Angulus (Peronidia) tumens n. sp.

Closely allied to the preceding species and intermediate between it and the Recent *A. edgari.* The ratio of length to height is not so great as that for *artus,* but greater than that for *edgari.* The characters of pallial sinus and hinge are identical in both the fossil species, but the ventral edge of valve is more convex in *tumens,* and its right valve is typically more inflated than that of either *artus* or *edgari.*

Height (right valve), 18.0 mm.; length, 29 mm.

Locality: Target Gully shell-bed, Oamaru (Awamoan).

Type and a number of paratypes in collection of Dr H. J. Finlay, Dunedin.

The characters separating *artus* from *tumens* are admittedly of subspecific significance only, but for the purposes of palaeontology it seems wisest to avoid the use of a trinomial.

The writer's thanks are due to Dr Finlay for permission to describe this species.

Genus FINLAYELLA n. gen.

Type: *Finlayella sinuaris* Laws.

This genus is provided to accommodate *F. sinuaris* n. sp. (described below) and *F. imbellica* (Marwick) from the Chatton sands. Several undescribed fossil species are also known.

Maoritellina was proposed by Finlay (*Trans. N.Z. Inst.*, vol. 57, p. 466; 1926) for *T. charlottae* E. A. Smith, but Marwick (*N.Z. Geol. Surv. Pal. Bull.* No. 13, p. 74; 1931) has pointed out that this genus is based on a misconception of *T. urinatoria* Suter. In the same place (loc. cit., p. 75) Marwick has described species agreeing well with Suter's figure of *M. charlottae*. In the absence of actual specimens of *charlottae* it is difficult to be sure of true *Maoritellina*, but the group seems to consist of flattened, moderately produced shells without rostral twist or lateral teeth. *Imbellica* and the present species are much more convex and trigonally ovate, and have distinct lateral teeth and rostral twist, and are evidently not *Maoritellinas*.

But the most curious feature of these two species, a feature that has led without hesitation to the creation of a new genus, and one so far seen in no other Tellinids, is the asymmetrical development of the pallial sinus in the right and left valves respectively (see description of species below). Three pairs of valves were collected, five valves at Sutherlands and one at White Rock River, and this peculiar feature of the sinus is found to be quite constant for each set.

The writer is pleased to name this genus in honour of Dr H. J. Finlay, of Dunedin.

Finlayella sinuaris n. sp. (Figs. 2, 3, 6).*

Shell small, fragile, well rounded over anterior end, strongly angled posteriorly. Beaks a little posterior. Antero-dorsal margin slightly curved; postero-dorsal one straight, descending more rapidly than antero-dorsal one. Posterior end bent to right. Sculpture of fine, dense concentric growth-lines, and in addition four or five sharp, distant lamella-like threads, regularly spaced and developed all around margins, and converging to beaks. Posterior flattened area carries several low, wide radial undulations. Right hinge wider in front than behind; it has two triangular cardinals, the posterior one bifid; the cardinals separated by a deep pit immediately below umbo; lateral teeth thin and sharp, anterior one arises nearer umbo than does posterior one. Left hinge with a narrow, vertical cardinal equally bifid and with wide triangular depressions on each side; hinge-plate not differentiated from margins of valves. Pallial sinus of right valve wide, sharply rounded at extremity, reaching a little over halfway across valve; that of left valve wide, very deep, bluntly rounded at extremity, reaching almost to anterior adductor scar. Valve margins smooth.

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* *Finlayella* has a Pliocene representative in *Macoma subtriquetra* Bartrum and Powell, a Waitotaran fossil from Kaawa Creek.

Height, 7.0 mm.; length, 9.2 mm.; thickness (one valve), about 1.2 mm.

Localities: Sutherlands, Tengawai River, South Canterbury (type and several paratypes); White Rock River, South Canterbury (a single left valve). These are Awamoan horizons.

Type in writer's collection.

The posterior angulation is more marked in this species than in *F. imbellica* (Marwick) and the shell is less equilateral.

Genus CONOMINOLIA Finlay, 1926.

Type: *Heliacus conicus* Marshall.

Conominolia woodsi n. sp. (Figs. 31, 39).

Shell small, spire elevated, conical; umbilicus rather narrow, strongly penetrating; shell ornamental with spiral cinguli. Spire stepped at sutures, its outlines straight usually, but in some shells a little convex. Protoconch polygyrate and pointed, nucleus very small; embryo unsculptured, probably of about two volutions, but brephic stage not definitely marked off from embryonic. The first post-nuclear whorl is marked by three weak spirals; the second still has three, but they are finely beaded; the next whorl carries four and the next five, the cinguli being now more conspicuously beaded. The body-whorl bears six spirals above periphery, and eight on the base, the eighth bordering the umbilicus, and being more strongly nodulated. All spirals are thin and sharply elevated, and are separated by wide, faintly concave interstices; the first spiral below suture is always the weakest. The beads on the cinguli occur where these cords are crossed by the quite distinct, evenly-spaced lines of growth, which are retracted from upper suture. Umbilicus perspective, unsculptured except for one or two spirals immediately below the nodulated peripheral cord. Base lightly convex. Aperture subrhombic; pillar obliquely set and sinuous. Height of spire about twice that of aperture.

Height, 4.5 mm.; diameter (greatest), 4.0 mm.

Localities: Sutherlands, Tengawai River, South Canterbury (type); White Rock River, South Canterbury; Holme Station, Pareora River; Opihi River; Target Gully shell-bed, Oamaru; Ardgowan shell-bed, Oamaru. All these are Awamoan horizons.

Type in writer's collection.

This is a very common fossil at Sutherlands and at White Rock River. The shells from the former locality are on the whole larger than the White Rock River ones, and have the spire somewhat more elevated.

The species is distingushed from *C. vixincisum* (Marwick) from Chatton, by its much stronger development of spiral corrugations and lack of any strong cord on periphery of body-whorl. *C. vixincisum* has a relatively much narrower umbilicus. Most of the Chatton shells are decorticated specimens, and it is rare to find one that has the outer layer preserved.

C. sulcatina (Suter) from the tuffs at Kakanui is a larger species, has six as against one spiral within the umbilicus, the spirals unequal and considerably stronger on the base than elsewhere, and more numerous (about 10 as against 6 in *woodsi*) above periphery of body-whorl.

C. conica (Marshall), the genotype, has upper spiral of whorls strongly beaded, the others much less so; the spirals are more numerous, about 6 as against 3 or 4 in *woodsi.*

Named in honour of Mr A. J. Woods, M.A., of Dunedin Training College.

Genus POLINICES Montfort, 1810.

Type: *Polinices albus* Montfort (= *Natica mammillaris* Lamk. = *Natica brunnea* Link).

Subgenus *Polinella* Marwick, 1931.

Type: *Uber obstructus* Marwick.

Polinices (Polinella) fryei n. sp. (Fig. 30).

Shell large, of fairly heavy build, not as elongate as *P. obstructus,* and body-whorl more swollen. Spire about half height of aperture, acuminate. Whorls 4½, the last two enlarging very rapidly, lightly convex, but body-whorl straight just below suture. Apertural callus not spread widely, descending somewhat narrowly over umbilical region, but not as narrow as that of *P. obstructus.* Funicular swelling present, but umbilicus well open anteriorly, though soon closing behind. Posterior end of callus separated from outer lip by a deep, narrow channel. Callus with two grooves, the lower one not distinct as result of abrasion; upper one placed almost exactly as is that of *P. obstructus,* the lower running horizontally across callus from a point near top of funicle, and not so low, therefore, as is that of the genotype.

Height, 41 mm.; diameter, 34 mm.

Locality: White Rock River, South Canterbury (Awamoan).

Type (unique) in writer's collection.

P. modestus (Marwick) is a much smaller species with almost flat spire-whorls and umbilicus entirely covered by callus.

Named in honour of Mr N. A. Frye, B.A., its discoverer.

Genus UBERELLA Finlay, 1928.

Type: *Natica vitrea* Hutton.

Uberella acerva n. sp. (Fig. 32).

Shell large for this genus, obliquely oval, spire rather elevated, stepped, whorls strongly convex. Protoconch with large nucleus, paucispiral. Whole surface covered by weak spiral lines, some finer than others, the strongest forming a subsutural ridge. Axial growth-ridges oblique, retrocurrent from upper suture, strong around subsutural border and over whole surface of last whorl towards outer lip. Suture abutting. Callus of aperture narrow, widest above and tapering downwards, a little swollen where bordering umbilicus, which is distinctly open but not wide. Outer lip strongly antecurrent to suture.

Height, 11 mm.; diameter, 9.0 mm.

Localities: Sandy clays above limestone, Blue Cliffs, South Canterbury (type); blue clays on left bank of Pareora River below lower end of Pareora Gorge. Both of these are Hutchinsonian horizons.

Type and many paratypes in writer's collection.

This species comes nearest to *U. pseudovitrea* (Finlay), but differs in being of larger size and in having more tabulated whorls, stronger spiral sculpture and wider umbilicus, with swelling on callus of umbilical border.

At Otiake there occurs a new species which has a more widely open umbilicus and less distinct funicle.

Genus HYALOSCALA de Boury.

1889. *Rev. Scal. d'Italie,* 14, p. 90.

Type: *Scalaria clathratula* A. Adams.

Hyaloscala muricata n. sp. (Figs. 19, 36).

Shell small, elongately conic, of about 7 post-nuclear whorls. Whorls strongly convex; suture well cut in. Sculpture of numerous, very oblique, thin, sharply raised lamellae, retrocurrent from upper suture, and about 30 on last whorl. Each rib is muricated just before reaching summit of whorl. The lamellae are continued to suture and twisted over just before reaching it. No spiral sculpture present. Embryo broken off. Aperture circular, peristome continuous, but thin over parietal wall. Columella arcuate. Ribs continued over base to umbilical region.

Height (estimated), 5.5 mm.; width, 2.0 mm.

Localities: Sutherlands, Tengawai River, South Canterbury (type); Ardgowan shell-bed, Oamaru (a fragment). Both are Awamoan horizons.

Type in writer's collection.

This species comes near to the Recent *H. jukesianum* (Forbes), but is slenderer and has thinner, closer, more oblique and muricated summits to axials. There is no trace of a fasciole swelling around the inner lip.

This is the first Tertiary representative of true Scalidae to be recorded from New Zealand, and since, so far as the writer knows, no Pliocene form has yet been found, *jukesianum* may possibly be exclusively a Recent development. As the Miocene species is rare, however, the possibility of a Pliocene representative cannot entirely be ruled out.

Genus EULIMA Risso, 1826.

Type: *Turbo politus* Linné.

Eulima otaioensis n. sp. (Fig. 25).

Shell large, elongate, conic, imperforated, surface shining. Outlines of spire straight. Protoconch not well seen, slightly tilted. Post-embryonic whorls 13½, early ones flat, later ones bulging below and overhanging succeeding volutions. Growth-lines fairly distinct and regularly spaced, antecurrent from upper suture. Over lower half of last few whorls the growth-lines are latticed at right angles by oblique, low, rather indistinct, raised lines, situated more than their own width apart. Varices oblique, sporadic. There are several faint spirals around periphery of last whorl, that on the periphery being the strongest. Aperture widely rounded in front, sharply angled behind; outer lip sinuous, thin, sharp; columella set vertically, arcuate, expanded at insertion.

Height, 19 mm.; width, 5 mm.

Locality: Sandy clays above limestone, Blue Cliffs, South Canterbury (Hutchinsonian).

Type (unique) in writer's collection.

This shell is extremely closely allied to the Australian *E. donae* Ten.-Woods, from which it differs mainly in size, the adult of *E. donae* being considerably larger. The Australian shell further has subsutural part of whorls more excavated and the swelling of lower portion more pronounced and wider; varices not so oblique; and the oblique lines crossing growth-lines are thin, wavy, irregular, and appear more like cracks in the outer layer of the shell. Fig. 24 represents a specimen of *E. donae* from the Janjukian beds at Gellibrand River, Victoria.

E. waihaoensis Allan, a Tahuian species from McCullough's Bridge, has periphery of body-whorl more sharply rounded, whorls flat and not overhanging, and suture quite indistinct.

Genus COMINELLA H. and A. Adams, 1853.

Type: *Buccinum maculosum* Gmelin.

Subgenus ACOMINIA Finlay, 1926.

Type: *Buccinum adspersum* Bruguière.

Cominella (Acominia) scirrifer n. sp. (Figs. 29, 33).

Shell of moderate size and of heavy build, periphery of whorls carinated. Spire a little less in height than aperture plus canal, its outlines straight. Whorls very much embracing, so that suture reaches up to the nodulated periphery, over which it undulates, obscuring the lower half of each nodule. Whorls excavated a little above carina, sometimes flat though. A wide subsutural swollen band is present, becoming more prominent and heavy on last whorl. Whole surface covered by flat, slightly wavy spiral cords, separated by interstices usually narrower than the cords; about 10 cords on shoulder, 11 on base between periphery and fasciole. Peripheral tubercles are distinct rounded knobs, 10 or 11 on penultimate whorl; only 7 on body-whorl, as they become obsolete towards aperture, i.e., over about last third of whorl. Fasciole strongly developed; a thick, heavy ridge arises just below middle point of inner lip and twists anteriorly to end at the deep notch of the canal. Between this ridge and the columella there is a fairly deep, wide depression, which narrows and steepens posteriorly to enter a small umbilicus. Lines of growth distinct, sinuous in conformity with curve of outer lip. Protoconch (tip decollated) of about two apparently smooth turns, only a little swollen.

Height, 34 mm.; width, 23 mm.

Locality: Sutherlands, Tengawai River, South Canterbury (Awamoan).

Type and a paratype in writer's collection.

This is probably the shell identified by Suter as *C. carinata* (Hutton) in the list of fossils from Sutherlands (*N.Z. Geol. Surv. Pal. Bull.* No. 8, p. 56, 1921). The angled periphery set with tubercles differentiates this species from others of similar build. It is probably nearest to *Acominia crassinodosa* Marwick (*N.Z. Geol. Surv. Pal. Bull.* No. 13, p. 116; 1931), but differs at sight in many respects, notably in having many and closer spirals on shoulder, taller spire, straight outline below periphery of body-whorl, and less heavy parietal callus.

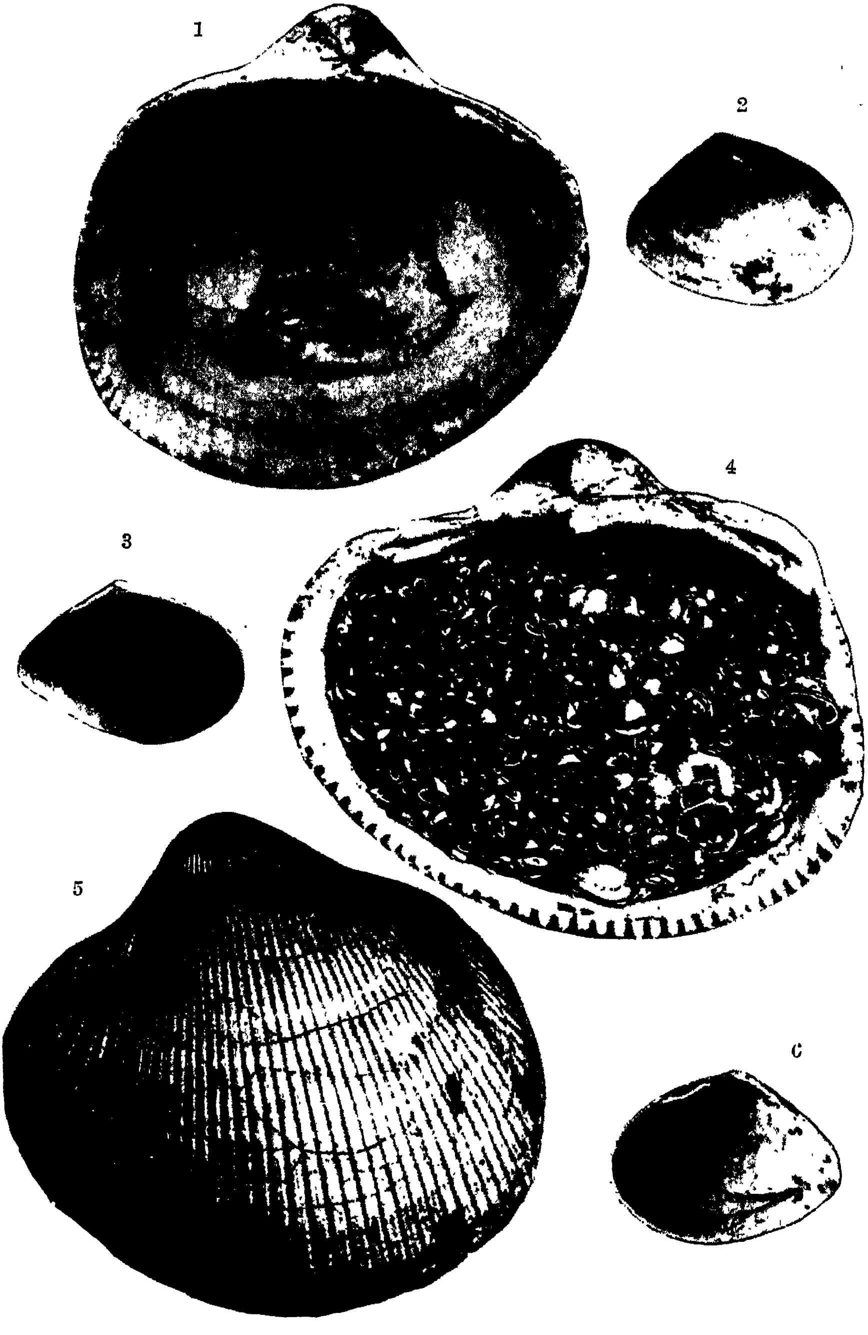
Genus ZAFRA A. Adams, 1860.

Type: *Zafra mitriformis* A. Adams.

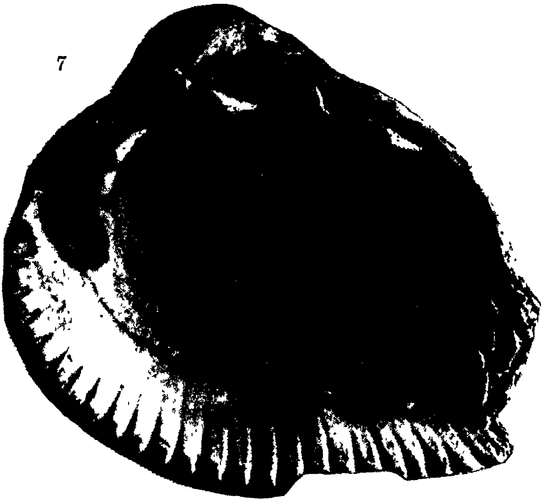
Zafra opihiensis n. sp.

Shell very small, spire conic, a little higher than aperture plus canal. Suture not very distinct, margined below by a swollen spiral band. Whorls very faintly convex. Outline of spire straight. Sculpture of axial ribs and spiral ridges. Axials (11 or 12 on penultimate whorl) extending across whole width of spire-whorls, but becoming obsolete below periphery of last whorl and towards outer lip; axials nodulated where crossed by the heavier spirals. Interspaces about same width as axials. The spirals are four in number on penultimate and antepenultimate whorls, the upper two strong and nodulating the axials. On body-whorl the two strong upper ones are still present, and several very faint spirals below them over centre of whorl; on the base there are 11 quite strong, regular spirals separated by grooves somewhat narrower than the ridges. Protoconch polygyrate and pointed. There are about four post-embryonic volutions. Aperture narrow, wider behind; a wide canal in front. Outer lip straight above, then bent round towards axis of shell to form side of anterior canal; five denticles within, becoming more prominent towards posterior. Columella ridged vertically by outer margin of callus; this ridge is a little nodulated where basal spirals pass under it. Columellar folds 2, the stronger below and only a faint swelling above; both well inside aperture.

Height, 4 mm.; width, 2 mm.



FIGS. 1, 4, 5.—*Trachycardium cantuariense* n. sp.; types, × 0·8.
FIGS. 2, 3, 6.—*Finlayella sinuaris* n. gen. et sp., × 3·2.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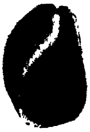
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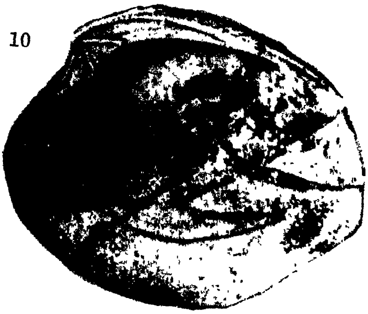
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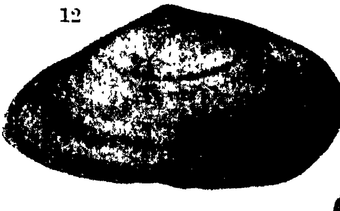
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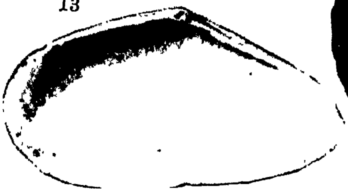
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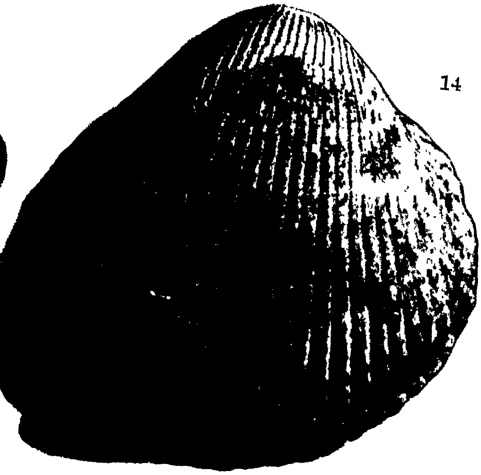
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FIGS. 7, 14.—*Cardium gudexi* n. sp.; holotype, × 0·8.
FIGS. 8, 9.—*Scaphander scapha* n. sp.; holotype, × 3·3.
FIG. 10.—*Bassina speighti* (Suter), × 1·1.
FIGS. 11, 12. 13.—*Angulus (Peronidia) artus* n. sp.; types, × 1·6.

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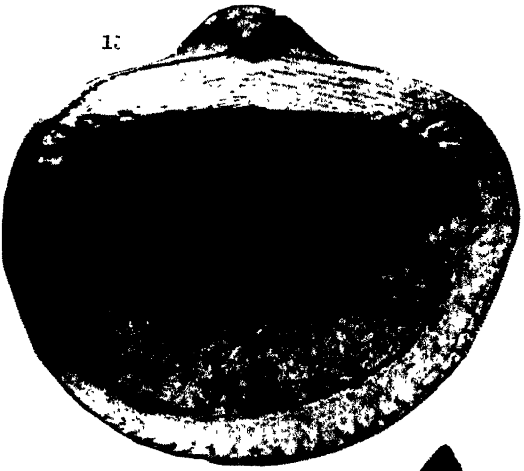

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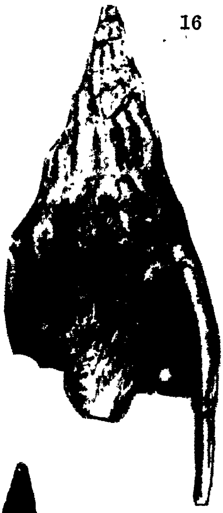

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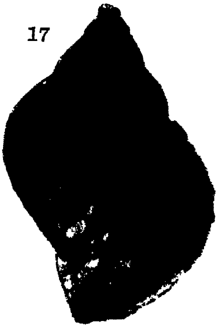

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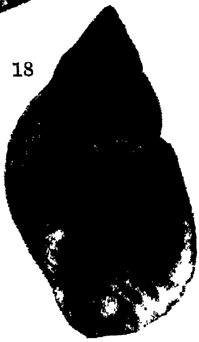

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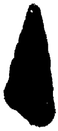

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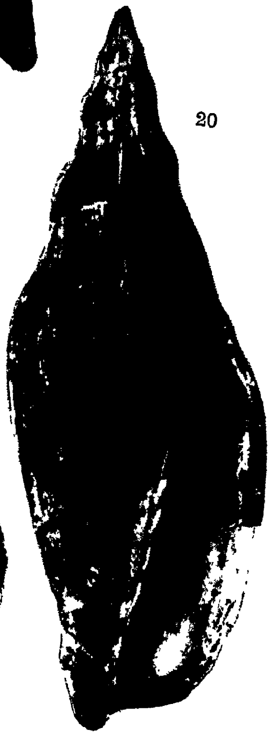

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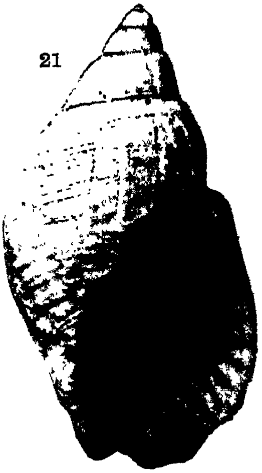

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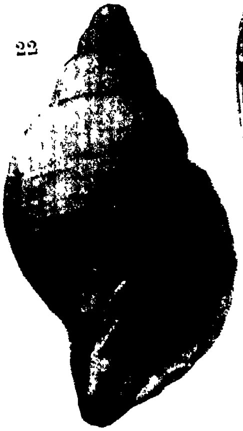

Fig. 15.—*Glycymeris thomsoni* Marwick, × 0·8.
Fig. 16.—*Spinomelon otaioensis* Laws; holotype, × 1·0.
Fig. 17.—*Maorivetia brevirostris* (Hutton), juvenile, × 1·5.
Fig. 18.—*Aphera (?) scopalveus* Finlay, Ardgowan, × 2·3.
Fig. 19.—*Hyaloscala muricata* n. sp.; holotype, × 3·1.
Fig. 20.—*Spinomelon evelynae* n. sp.; holotype, × 0·7.
Fig. 21.—*Aphera (?) scopalveus* Finlay, topotype, × 2·1.
Fig. 22.—*Maorivetia brevirostris* (Hutton), juvenile, × 3·2.

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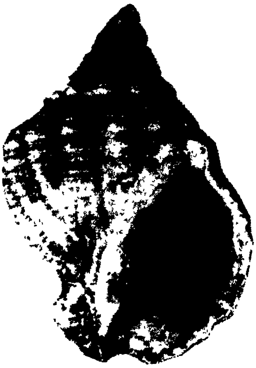

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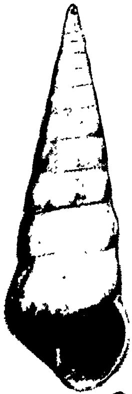

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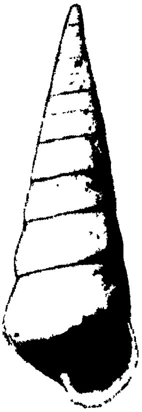

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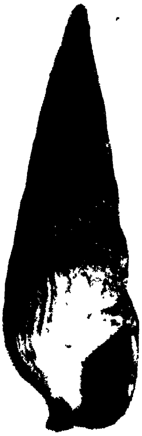

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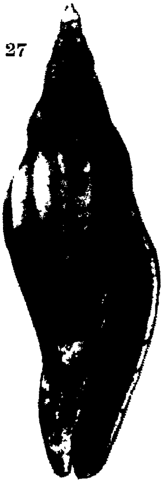

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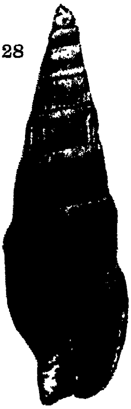

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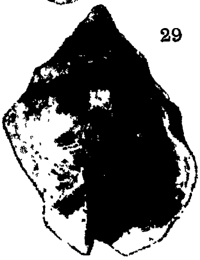

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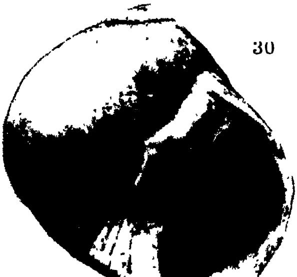

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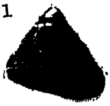

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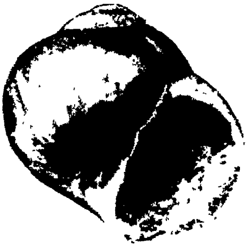

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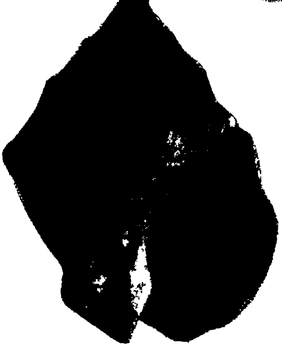

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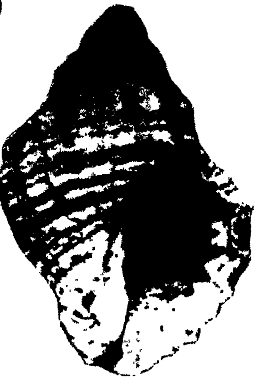

FIG. 23.—*Maorivetia brevirostris* (Hutton), × 1.1.
FIG. 24.—*Eulima donae (Tennison-Woods),* × 2·1.
FIG. 25.—*Eulima otaioensis* n. sp.; holotype, × 3·2.
FIG. 26.—*Zeacuminia cantuariensis* n. sp.; holotype, × 2·4.
FIG. 27.—*Spinomelon evelynae* n. sp., juvenile, × 1·1.
FIG. 28.—*Zeacuminia cantuariensis* n. sp.; paratype, × 2·4.
FIG. 29.—*Cominella (Acominia) scirrifer* n. sp.; holotype, × 1·0.
FIG. 30.—*Polinices (Polinella) fryei* n. sp.; holotype, × 1·1.
FIG. 31.—*Conominolia woodsi* n. sp.; holotype, × 3·2.
FIG. 32.—*Uberella acerva* n. sp.; holotype, × 3·3.
FIG. 33.—*Cominella (Acominia) scirrifer* n. sp.; holotype. × 1·5.

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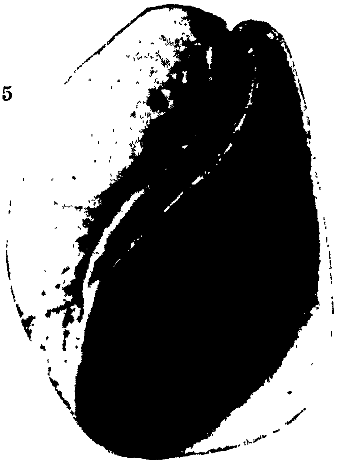

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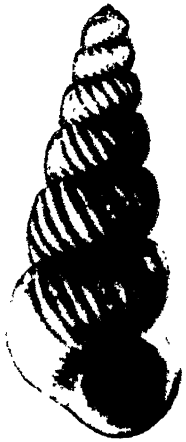

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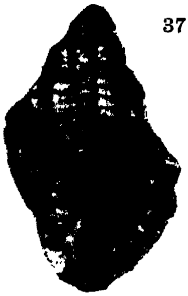

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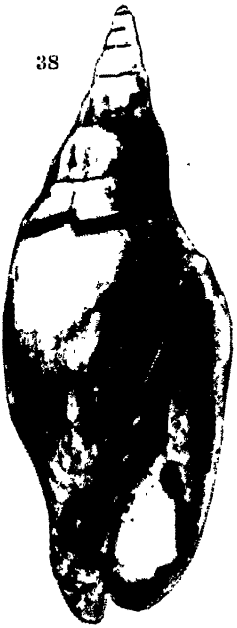

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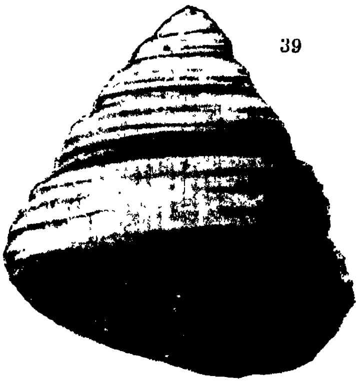

FIG. 35.—*Scaphander scapha* n. sp.; holotype, × 9·6.
FIG. 36.—*Hyaloscala muricata* n. sp.; holotype, × 9·6.
FIG. 37.—*Cronia tengawaica* n. sp.; holotype, × 2·0.
FIG. 38.—*Spinomelon otaioensis* Laws; topotype, 0·8.
FIG. 39.—*Conominolia woodsi* n. sp.; holotype, × 10·2.

Locality: Opihi River, South Canterbury (Awamoan). The outcrop is about three miles above the confluence of the Opihi and Tengawai Rivers, in bluffs on the left side of the river.

Type (the only specimen) in the writer's collection.

This species resembles *Z. darwini* Angas as figured by Hedley (*P.L.S.N.S.W.*, 39, p. 740, Pl. 83, Fig. 74) from Queensland.

An undescribed related species with taller spire, lacking the subsutural spiral tumidity of *opihiensis* and possessing other differences in sculpture, occurs in the shell-bed at Target Gully, Oamaru.

A figure of this shell will be supplied in a later paper.

Genus CRONIA H. and A. Adams, 1853.

Type: *Thais amygdala* Kiener.

Cronia tengawaica n. sp. (Figs. 34, 37).

Shell small, solid, turriculate. Spire a little less in height than aperture plus canal. The sculpture consists of prominent rounded, distant axial ribs (10 on body-whorl), a little over their own width apart, extending entirely across spire-whorls, though weaker on the shoulder, and reaching almost to anterior end of base. Spiral cords are strongly developed. On spire-whorls the strongest cord is on the carina which is about central; on body-whorl there are two especially prominent cords, one at the periphery and the other just below. The penultimate whorl has 8 spirals; the body-whorl carries 6 on the shoulder (the third one above periphery stronger than the others), and about 7 main ones below periphery, with a number of interstitial riblets. The axials are nodulated where crossed by cords, the strongest nodulations being on the keel. The cords in places are slightly scaly where crossed by growth-lamellae. Aperture much as in *C. pseudamygdala,* narrowly oval, channeled behind; a short, moderately wide, deep canal in front. Inner lip depressed, callused thinly. There is a wide, shallow groove on columella just below point of origin of fasciole, which is moderately strong. Outer lip with 8 quite prominent denticles a little inside. Nuclear whorls absent.

Height (estimated), 18 mm.; width, 10 mm.

Locality: Sutherlands, Tengawai River, South Canterbury (Awamoan).

Type (unique) in writer's collection.

The shell resembles *Lepsiella* somewhat, but has not been referred to that genus because of the deep notch of the anterior canal. It is more like *Cronia* in sculpture and general appearance, but has more shouldered whorls, stronger denticles within outer lip, and more ridged pillar. It is not smooth enough for *Agnewia,* and has no internal lirations as has that genus, so that in the meantime it seems best placed in *Cronia.*

The present shell has been compared with specimens of *C. pseudamygdala* (Hedley) from Sydney, from which it differs mainly in being a smaller shell with sutures not so high up, spire more stepped, and pillar more excavated. Both species are closely similar in sculpture, and carry 10 axials on the body-whorl.

Cronia along with other genera of the Thaididae is typically a littoral genus. So far the only other fossil species belonging to this family to be recorded from New Zealand are *Lepsiella intermedia* and *L. maxima,* both members of the Hutchinsonian fauna at Oneroa, Waiheke Island, described recently by Powell and Bartrum (*Trans. N.Z. Inst.,* vol. 60, p. 438; 1929).

VOLUTIDAE.

The following Volutes have been recently obtained from the blue clays at Blue Cliffs, Otaio River, South Canterbury.

Waihaoia (Teremelon) aff. *tumidior* (Finlay) and *awamoaensis* Marwick.

Spinomelon turrita (Suter). Topotypes.
„ sp. (also from Opihi River and Sutherlands).
„ n. sp. aff. *henryi* Laws.
„ *otaioensis* Laws. Topotype.
„ *evelynae* n. sp. (described below).
Metamelon aff. *prominima* Laws and *inermis* (Finlay).
Alcithoe cf. *lepida* Marwick and *reflexa* Marwick.
„ n. sp. aff. *scopi* Marwick.

Spinomelon evelynae n. sp. (Figs. 20, 27).

Shell large, spire three-quarters height of aperture. Embryo of two smooth turns, calcarella erect and sharp. Post-nuclear whorls about six, convex, with a wide, sloping, lightly concave shoulder; height of whorl relatively greater than that of *S. parki* (Suter). Body-whorl long, narrow, contracting slowly over base; fasciole prominent. Whorls strongly embracing and suture very tangential. Axial ribs 14 on upper whorls, 16 on last whorl; they are thin, moderately elevated, distant, and almost obsolete on shoulder of later whorls, but distinct across entire width of early post-nuclear whorls; on body-whorl the axials extend about half distance towards anterior end. Aperture and canal much as in *S. parki.* Columella a good deal less swollen over plaited portion than is that of *parki,* and the folds are six in number (posterior one very weak) and not so prominent. Outer lip convex, reflected, ascending penultimate whorl a little. Inner lip widely spread in characteristic *Spinomelon* fashion.

Height, 140 mm.; width, 43 mm.

Locality: Blue Cliffs, Otaio River, South Canterbury, blue sandy clays above limestone (Hutchinsonian).

Type and a number of fragmentary and juvenile paratypes in writer's collection.

This species is a very close relative of *S. parki,* but it is a more slender shell with higher spire, less swollen pillar with rather weaker folds, and has well developed axials persisting to outer lip. Fig. 27 represents a juvenile shell, and shows well the much greater elongation of this species.

Named in honour of my wife.

Spinomelon otaioensis Laws (Figs. 16, 38).

This species, which was described, but not figured, in a paper previously published*, is now illustrated. Fig. 38 is that of a shell, more complete than the type, which has been collected quite recently.

ZEACUMINIA Finlay, 1930.

Type: *Terebra sulcata* Marshall.

Zeacuminia cantuariensis n. sp. (Figs. 26, 28).

Related to *Z. pareoraensis* (Suter), with which it is associated at both the localities given below. It is, however, typically a stouter shell with a wider body-whorl. It is immediately separable from *Z. pareoraensis* by the nature of its axials, which are very fine, almost hair-like, closer, and much more numerous. On the penultimate whorl there are 32 to 34 axial ribs as against 20 in *pareoraensis.*

Height, 26 mm.; width, 7 mm.

Localities: Sutherlands, Tengawai River, South Canterbury (type); White Rock River, South Canterbury (two specimens).

Type and nine paratypes in writer's collection.

Z. pareoraensis is very plentiful at both of the above localities, White Rock River being the type locality for this species. Suter (*N.Z. Geol. Surv. Pal. Bull.* No. 5, p. 62; 1917) also records it from Blue Cliffs, but it was not found by the writer, who spent two days collecting at that locality. *Z. biplex* (Hutton) was, however, found to be quite common there.

Genus SCAPHANDER Montfort, 1810.

Type: *Bulla lignaria* Linné.

Scaphander scapha n. sp. (Figs. 8, 9, 35).

Shell small, fragile, narrower behind, wide across anterior, not umbilicate. Spire involute, apical pit fairly wide and deep; body-whorl embracing, and hiding all earlier volutions. Aperture very narrowly channelled behind, widely open and rounded in front; parietal wall covered by a thick callus; columella long, thin, arcuate. Sculpture of about 40 spiral cords (often arranged in pairs) separated by interstices whose width is subequal to that of cords.

Height, 5.5 mm.; diameter, 3.5 mm.

Localities: Sutherlands, Tengawai River, South Canterbury (type); Ardgowan shell-bed, Oamaru (a fragment). Both of these are Awamoan horizons.

Type and a paratype in writer's collection.

This species cannot be confused with *S. malleatus* Marwick, the only other one so far described from New Zealand. A related species occurs in the Ototaran beds at Chatton, and a larger, taller, and quite distinct species has been obtained from the Awamoan beds at Holme Station, Pareora Gorge.

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* *Trans. N.Z. Inst.*, vol. 62 (1932), p. 193.

Globisinum marwicki Laws. (*Trans. N.Z. Inst.*, vol. 61, p. 551; 1930.)

This species was founded on a single specimen from White Rock River. Two other specimens have since been collected, one at Holme Station, Pareora Gorge, and another at Sutherlands.

Maorivetia brevirostris (Hutton). (*Trans. N.Z. Inst.*, vol. 9, p. 596; 1877.)

This species occurs very abundantly at both White Rock River (the type locality) and at Sutherlands; it has also been collected at Holme Station, Opihi River, Dyer's Run (near Mt. Harris). In North Otago it is not uncommon at Ardgowan and at Target Gully. The holotype is a badly worn shell, as are most of the specimens from the type locality. Fig. 23 represents a very perfect shell collected at Sutherlands, and may be regarded practically as a topotype.

Aphera (?) scopalveus Finlay. (*Trans. N.Z. Inst.*, vol. 56, p. 246; 1926.)

Dr Marwick (*N.Z. Geol. Surv. Pal. Bull.* No. 13, p. 121; 1931) has stated his belief that this species is but the juvenile form of *M. brevirostris* (Hutton). The writer has recently collected two shells at Ardgowan, and one at Target Gully, all of which agree exactly with Dr Finlay's *A. scopalveus.* The development of apertural callus and thickened, corrugated outer lip show at once that these shells are adult. Differences from *M. brevirostris* other than that of sculpture are not wanting. *A. scopalveus* has constantly a smaller and sharper protoconch; the last whorl is less convex with a perceptible flattening out of body-whorl above towards the aperture (i.e., the outer lip expands below); the body-whorl is not rapidly contracted to axis below periphery; and there is no wide, deep channel above the fasciole. There seems, then, no necessity to consult the sculpture in order to establish specific distinction between these two forms. Figs. 17 and 22 represent juveniles of *M. brevirostris* inserted for comparison with *A. scopalveus* (Figs. 18, 21).

Bassina speighti (Suter) (Fig. 10).

The types come from the lower Gorge of the Waipara (lower horizon), and they are embedded in matrix. Dr Marwick in his revision of the Veneridae records the species from several North Island localities, the only South Island record being a fragment from Chatton. The writer has collected several specimens from Sutherlands, South Canterbury, and one of these, a complete right valve, is figured here, as Marwick's drawings represent only fragments. It will be seen that the pallial sinus is narrower, more acutely angled, and much longer than that of the Recent species, *B. yatei.* Dr Finlay has *speighti* also from Target Gully shell-bed and from horizon 8, Clifden, Southland (two broken specimens).

Height, 39 mm.; length, 45 mm.

Dosinia lambata Gould.

This Recent species has an extended range in time, for Dr Marwick records it from the beds at Trig. Z, Otekaike, Waitaki Valley (*Trans. N.Z. Inst.*, vol. 57, p. 584, 1927). Recently several good specimens have turned up at Sutherlands. Close comparison of these with Pliocene and Recent shells provides no means of making a good separation, the only observable differences being that the Miocene shells are rather less inflated, of lighter build, and a little more produced posteriorly. In the characters of hinge and sinus they all agree entirely.

Glycymeris robusta Marwick.

In addition to a large number of specimens of *G. huttoni* Marwick, collected at Sutherlands, six fine valves agreeing very closely with topotypes of *G. robusta* were obtained. *G. robusta* was found also at Opihi River and at a small outcrop on the right bank of the Otaio River, about two miles downstream from the blue clays at Blue Cliffs. The fauna and lithology at this restricted outcrop are a repetition of those at Sutherlands and at Holme Station.

Glycymeris thomsoni Marwick (Fig. 15).

A fine large specimen of this species has been collected at Otiake. It has been compared with topotypes of *thomsoni* from Chatton, and is here figured.

Studies in New Zealand Fishes.

By L. T. Griffin, F.Z.S., Assistant Director Auckland Museum.

[*Read before the Auckland Institute, 28th September, 1932; received by the Editor, 3rd October, 1932; issued separately, June, 1933.*]

Plate 34.

During the collecting season of 1928 I obtained at Deep Water Cove, Bay of Islands, three specimens of *Acanthoclinus* which differed from the usual form of *A. quadridactylus.*

Recently I received a similar specimen from Mr A. Blackwell, of Tryphena, Great Barrier Island, which confirms the specific distinction of these forms from the well-known "*taumaka*" of the Maoris, hitherto the only species of *Acanthoclinus* known in New Zealand.

The new species, which is named *Acanthoclinus trilineatus,* differs markedly from *A. quadridactylus* in the disposition of the lateral lines as set out in the key given below. I have also given a description with drawings of both species.

Family Acanthoclinidae.

Genus *Acanthoclinus* Jenyns, 1842, Orthotype, *A. fuscus.*

Key to Species.

Fig. 1.—Lower lateral line system bifurcate extending over the abdomen to tips of ventrals.	*quadridactylus.*
Fig. 2.—Lower lateral lines not bifurcate.	*trilineatus* n. sp.

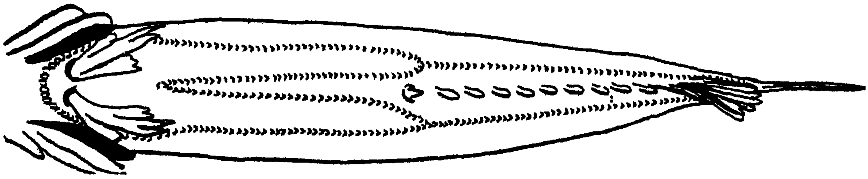


Fig. 1.—Ventral surface of *Acanthoclinus quadridactylus*, showing system of the lower lateral lines.

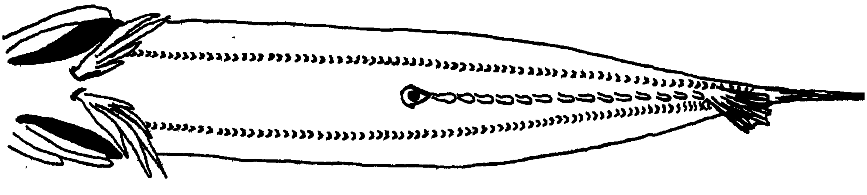


Fig. 2.—Ventral surface of *Acanthoclinus trilineatus* n. sp., showing lower lateral lines.

Acanthoclinus quadridactylus (Bloch & Schn.)

Maori, Taumaka. Plate 34.

1801. *Blennius quadridactylus,* Forster, in Bloch & Schn., *Syst. Ichth.,* p. 177.

1872. *Acanthoclinus littoreus,* Forster; Hutton, *Cat. Fish. N.Zeal.,* p. 34.

1879. *Acanthoclinus taumaka* Clarke, *Trans. N.Z. Inst.,* 11, p. 293, pl. 15.

1889. *Acanthoclinus fasciolatus* Ogilby, *Aust. Mus. Mem.,* 2, p. 63.

1923. *Acanthoclinus littoreus* Oliver, *Trans. N.Z. Inst.,* 54, p. 510, pl. 42.

1927. *Acanthoclinus quadridactylus* Phillipps, *Marine Dept. Fish. Bull.,* No. 1, p. 49.

Br. 6; D. xx/IV; A. ix/IV; V. IV; P. XVI; C. XVI.

Depth at centre of body 4.92; head 3.5; pectoral 6.28; in the length to base of middle caudal rays. Eye subequal with the interorbital space, and 7.43 in the head. Upper lateral line with 85 scales, middle lateral line with 64, and the lower with 42 not counting those extending on to the abdomen.

Body elongate, rather robust and rounded anteriorly, becoming gradually depressed towards the peduncle, where it is greatly so. Whole of body and nape covered with small closely set fleshy scales, but the head and throat are scaleless. Numerous open pores are present behind the eyes, extending over the top of the head.

The upper lateral line passes close to the base of the dorsal fin and reaches the caudal; it is connected anteriorly with a short branch line which surrounds the first dorsal spine. The middle lateral line commences at the margin of the pectoral, when the latter is adpressed, and continues straight to the base of the middle caudal rays. It is of uniform width throughout, and only slightly narrower than the upper line, but subequal with the lower.

The third lateral line surrounds the ventrals, then passing along the lower side of body, it bends slightly at the first anal spine, from thence it is straight to the caudal. There is an abdominal branch line connected to the above commencing above the first anal spine, which extends forward up the middle line of belly to the tips of ventrals, where it turns sharply to form the same connection on the other side of the fish.

Head covered with very tough skin; eye moderate, nearly cutting the profile. Two nostrils, one situated on the anterior margin of the orbit surrounded with a low rim, the anterior nostril is near the margin of the preorbital, and is provided with flaps which can be completely closed.

Maxillary nearly reaches the vertical of the posterior margin of the eye. Preorbital narrow. Mouth oblique, the lips thickened with tough skin. Minute villiform teeth in both jaws forming a broad band in front, among which are some slightly longer ones. Teeth are also present on the vomer and palatine bones, while the tongue has a triangular elongated patch in the centre.

Gills 4; gill-rakers 10 on the lower half of the anterior limb. Pseudobranchiae present. Dorsal fin commencing above the base of pectoral covered with thickened membrane, the terminating membranes of the spines being produced into small fleshy lobes. The anal fin is in every way similar to the dorsal. Caudal and pectoral rounded and otherwise similar to each other. Ventrals thoracic, fleshy.

Colour: Brownish to dull slate grey, paler on the ventral surface, sometimes showing a trace of pink. Some specimens are covered with irregular dark mottlings on the body while others appear quite plain—dark markings are also present on the membrane of all fins except the pectoral. The lobe-like tips of the spines in the dorsal and anal pinkish. Ventrals and pectorals dusky grey. Eye dark brown. Head same as body colour, and with two broad blackish streaks, one reaching from the lower margin of the orbit across the cheek, the other at top of cheek. There is also a dark blotch on the operculum.

Described and figured from a specimen which is 177 mm. long from the tip of the lower jaw to the base of the middle caudal rays. The head is 51 mm.; eye 7 mm.; depth of body 36 mm.

Altogether over 40 specimens of this fish have been critically examined, ranging in size from 20 mm. to as much as 205 mm. long, and I can find no variation whatever. In every case the fin formula was identical with the specimen here described, and all other characters are comparative.

Locality: Common throughout the Auckland Provincial District; living under stones, in rock pools, also on tidal flats wherever seaweed and boulders occur.

Specimens in the Auckland Museum.

Acanthoclinus trilineatus n. sp. Plate 34.

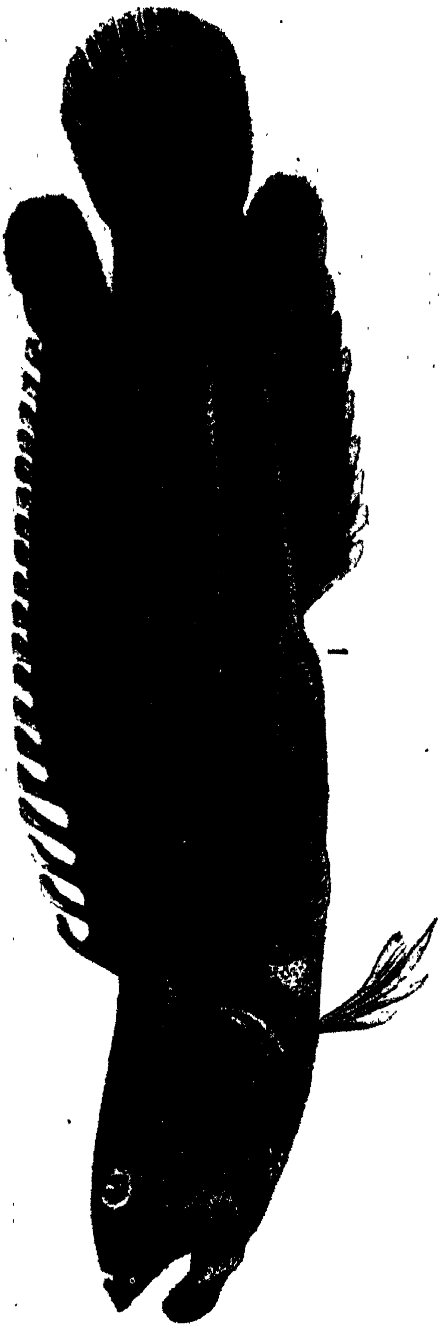
Br. 6; D. xxv/IV; A. xiv/IV; V. IV.; P. XIX; C. XV/$\frac{2}{3}$.

Depth at centre of body 6.06; head 4.22; pectoral 6.47 in the length to the base of the middle caudal rays. Eye subequal with the interorbital space and 7.67 in the head. Dorsal lateral line with about 88 series of scales; middle line 70; and the ventral line 86-88.

Body elongate, moderately robust anteriorly, becoming depressed very gradually towards the peduncle.

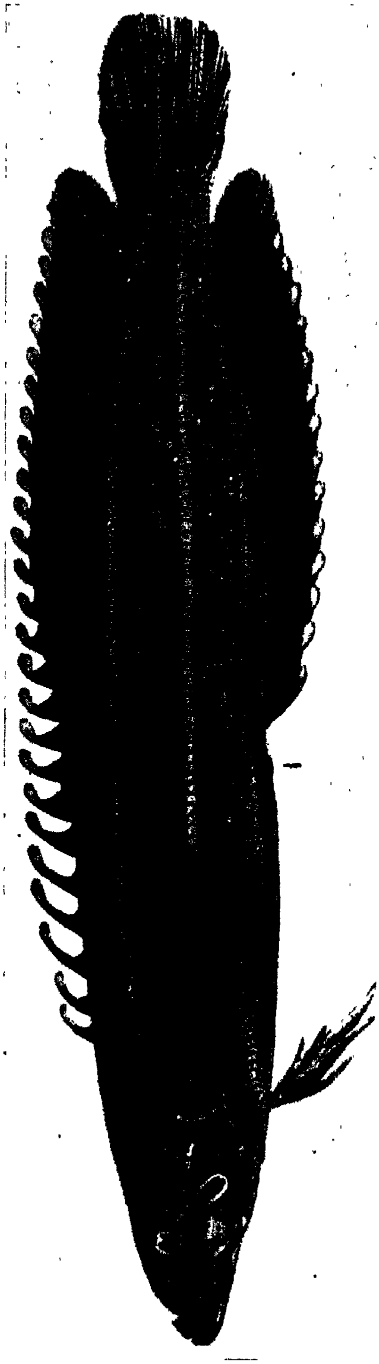
Whole of body including the throat covered in very small fleshy scales, but the head and nape are entirely naked. A number of small open pores are present behind the eyes and distributed about the top of the head.

Dorsal lateral line commencing at the upper angle of the operculum, passes along the back close to the base of the dorsal fin, and reaches the procurrent rays of the caudal. The middle lateral line



L. T. Griffin del.

Acanthoclinus quadridactylus (Bloch & Schn.).



is broadest, its origin is the middle of the pectoral, from thence it continues straight to the base of the middle caudal rays.

The ventral lateral line is about the same width as the dorsal one. Its origin is at the angle of the first ventral ray. It then follows the margin of the abdomen, rising slightly above the first three anal spines, then passes in a gradual curve to the lower procurrent rays of the caudal.

Head covered with tough skin. Eye rather small, subequal with the interorbital space, and barely cutting the profile. Two nostrils, the anterior, situated about the middle of the snout, is provided with a flap. The posterior nostril is divided into two low orifices resembling pores, and is situated on the anterior margin of the orbit.

Maxillary reaches backwards a considerable distance behind the eye. Margin of the cheek crenated. Margin of operculum with a transparent crenated fringe. Mouth oblique, the lower jaw longest. Minute villiform teeth in both jaws—forming a fairly uniform band in front. Teeth are also present on the vomer and palatine bones, but the tongue is smooth. Gills 4; gill-rakers 7 on the lower half of the anterior limb. Pseudobranchiae present.

Dorsal fin origin above base of pectoral, the first five spines with very low membrane, the membrane increases from the sixth to the tenth spine, where it reaches the produced fleshy lobes, and continues so to the end of the fin.

The anal is similar to the dorsal except that the membrane fills all the spaces between the spines. Pectoral and caudal are much alike in form. Ventrals thoracic, the rays split at tips.

Colour: Body purple brown with darker mottling between the lateral lines. Dorsal and anal with the fleshy lobes pinkish orange. Caudal same as body colour, pectoral clear slate with a dark band round the base. Ventrals dull orange, the tips white. Ground colour of the head same as the body, but with a conspicuous blue-black streak from the eye to the maxillary, another from the eye to the operculum, and there is a very large blue-black spot on the latter. All the streaks and the opercular spot are broadly margined with white. Eye brown, the pupil blue.

Described and figured from a specimen which is 98 mm. long from tip of lower jaw to base of caudal. The head is 25 mm.; eye 3 mm.; greatest depth of body 17 mm.

Locality: Only four specimens of this fish have so far been procured, three of which I took myself from rock-pools at Deep Water Cove, Bay of Islands, while the fourth has just been sent to the Museum from the Great Barrier Island. Those which I obtained I found living in the same rock-pools as *A. quadridactylus*, but *A. trilineatus* appears to be a much rarer species. A very critical examination discloses no variation whatever in the specimens obtained.

Holotype and paratypes in the Auckland Museum.

Tertiary Molluscan Faunas from the Southern Wairarapa.

By L. C. King, M.Sc., F.G.S., Victoria University College, Wellington.

[*Read before the Wellington Philosophical Society, 9th September, 1931; received by the Editor, 6th November, 1931; issued separately, June, 1933.*]

Introduction.

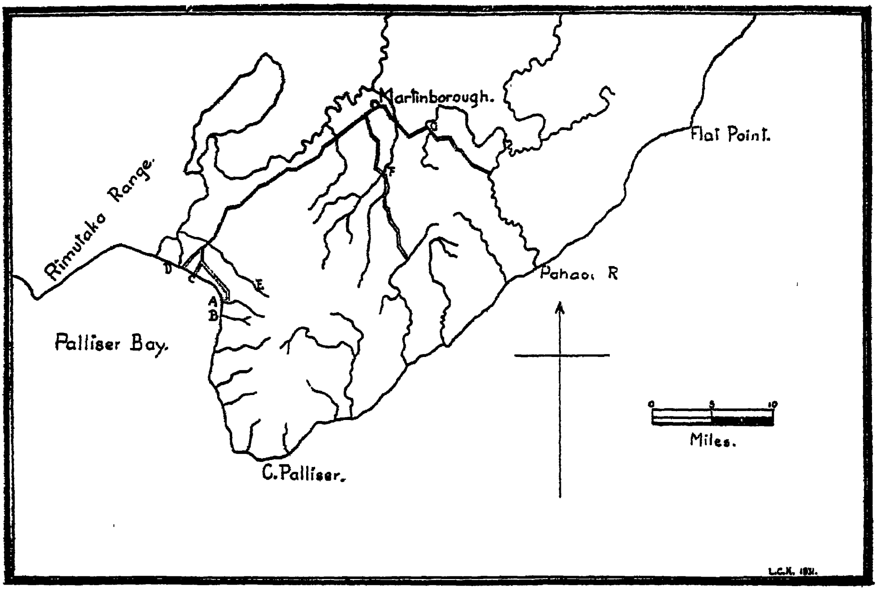
Though detailed descriptions of the faunas of fossil localities in the Southern Wairarapa have not been previously published, Waghorn (1927) has recorded lists of fossils from the Ruakokopatuna Valley, S. Wairarapa, and Marwick has at various times described new species of mollusca from Hurupi Creek, Palliser Bay (N.Z.G.S. Locality 1037). Powell (1929) has also described *Ellicea carinata* from the cliffs east of Lake Ferry, Palliser Bay.

The Tertiary rocks, as mapped by McKay (1879), strike north-east and dip consistently to the west. Along the north-east portion of Palliser Bay, Miocene rocks (Hurupi Creek Beds) overlie the greywacke basement, but, in the Ruakokopatuna Valley to the north-east, greensands and limestones of a somewhat younger (?) age rest directly upon the oldermass (Waghorn 1927, p. 230). Farther to the north-east a more complete sequence of Notocene rocks is present, and the basal members are probably even Cretaceous in age. A feature of this sequence is an immense thickness of unfossiliferous "papa" mudstones which underlie the fossiliferous limestones, brown sands, and mudstones of Pliocene age. Part of these unfossiliferous mudstones is no doubt equivalent in age to the Hurupi Creek beds of Palliser Bay, i.e., they may be correlated with the Tutamoe beds of the Gisborne Subdivision, which are also notably unfossiliferous. This has already been remarked by Henderson (1929, p. 281), who says: "The oldest Miocene rocks definitely identified by means of fossil collections are of Tutamoe age (Awamoan), but some of the underlying mudstones, in which no fossils have as yet been found, are undoubtedly Hutchinsonian."

HURUPI SERIES.

The Hurupi Creek Beds were described by McKay (1878, p. 19), and assigned to the Upper Miocene. Subsequently little descriptive work has been done, but the following authors have made brief reference to the beds:—McKay (1879, p. 81) = Lower Miocene (Pareora); Thomson (1919, p. 7) = Oamaruian, probably Awamoan; Marwick (1927, p. 576) = Mokau (Awamoan); Henderson (1929, p. 281) = Tutamoe (Awamoan); King (1930, p. 506) = Miocene; King (present paper) = Tutamoe (Awamoan).

The beds outcrop along a considerable portion of the north-east coast of Palliser Bay and for about half a mile inland, good exposures being obtainable in the sea-cliffs and the ravines which traverse the ancient marine terrace. As all collections have proved remarkably uniform no zoning upon palaeontological evidence is attempted, and the fauna of the beds outcropping in the Hurupi Creek has been taken as typical of the whole. Apart from this type locality, the best collections can be obtained from the Putangirua (or Pinnacle) Creek a mile to the south. One or two species not yet recorded from Hurupi Creek, but obtained from the Putangirua Creek, are therefore included in the general fauna. These beds have now been traced to the north-east as far as the Turanganui River. (Locality E.).



SKETCH MAP OF THE SOUTHERN WAIRARAPA, SHOWING FOSSIL LOCALITIES REFERRED TO IN THIS PAPER.

A. Hurupi Creek.
B. Putangirua Creek.
C. Whangaimona.
D. Lake Ferry.
E. Marls 1 mile below Turanganui Gorge.
F. Junction Ruakokopatuna and Makara Streams.
G. Junction Martinborough, Gladstone, and Hinakura Roads.

FAUNA OF HURUPI SERIES.

Bolma colini King.
Zeacolpus cf. *fyfei* Marwick.
Zeacolpus n. sp.
Pareora striolata (Hutton).
Struthiolaria subspinosa Marwick.
Struthiolaria sp. cf. *praenuntia* Marwick.
Callusaria callosa (Marwick).
Maoricrypta wilckensi Finlay.
Polinices mucronatus (Marwick).
Polinices huttoni v. Ihering.
Melanella tutamoensis Marwick.
Verconella crawfordi (Hutton).
Austrofusus marwicki n. sp.
Zelandiella subnodosa (Hutton).
Acominia hendersoni (Marwick).
Cominista putangirua n sp.
Antizafra wairarapa n. sp.
Waihaoia rugosa Marwick.
Alcithoe dilatata Marwick.

Alcithoe hurupiensis Marwick.
Baryspira cf. tirangiensis (Marwick).
Baryspira subhebera (Marwick).
Comitas abnormis n. sp.
Austrotoma cf. *scopalveus* Finlay.
Austrotoma sp.
Zeacuminia orycta (Suter).
Dentalium solidum Hutton.
Cadulus cf. teliger Finlay.
Anomia cf. *trigonopsis* Hutton.
Glycymeris hurupiensis Marwick.
Cucullaea sp. cf. *ponderosa* Hutton.
Limopsis lawsi n. sp.
Modiolus altijugatus Marwick.
Pedalion fortissimum n. sp.
Lentipecten hochstetteri (Zittel).
Ostrea sp.
Divaricella notocenica n. sp.
Macoma cf. *robini* Finlay.
Dosinia cottoni Marwick.
Marama hurupiensis Marwick.
Eumarcia thomsoni Marwick.
Eumarcia crassatelliformis Marwick.
Panope worthingtoni Hutton.

Fauna from Hurupi Beds 1 mile below Turanganui Gorge, South Wairarapa.

Zeacolpus cf. *fyfei* Marwick.
Zeacolpus n. sp.
Callusaria callosa (Marwick).
Maoricrypta wilckensi Finlay.
Austrofusus marwicki n. sp.
Baryspira sp.
Comitas imperfecta n. sp.
Cucullaea sp. cf. *ponderosa* Hutton.
Limopsis lawsi n. sp.
Modiolus altijugatus Marwick.
Limatula sp.
Macoma cf. *robini* Finlay.
Dosinia cottoni Marwick.
Marama hurupiensis Marwick.

ONOKE SERIES.

The Pliocene rocks outcrop as a strip margining the Hurupi Series to the west. No doubt several stages are represented (from Waitotaran upwards), but only one has been found, as yet, to be fossiliferous, namely a stage equivalent to the Nukumaruan. Collections have been made from the following localities:—Palliser Bay, sea cliffs between Lake Ferry and Whangaimona; Turanganui River, marls to the west of the Miocene (= Hurupi Creek) marls; Junction of the Ruakokopatuna and Makara Streams, East Coast Road, 5 miles east of Martinborough; Te Awaite Cutting,* ½ mile east of the above stream junction; the Junction of the Martinborough, Gladstone, and Hinakura Roads; and 1½ to 3 miles up the Ruakokopatuna Road, Ruakokopatuna Valley.

In the natural section exposed in Palliser Bay a great thickness of unfossiliferous mudstones occurs between the Tutamoe rocks of Hurupi Creek and the Nukumaruan mudstones of Whangaimona. These mudstones may be taken as Waitotaran in age. In the lower portion of the sequence a slight disconformity may be present, but the exposure is not very clear. Between Whangaimona and Lake Ferry the fossiliferous mudstones of Nukumaruan age outcrop along the coast. To the west of Lake Onoke, as far as the Rimutaka fault at the north-west corner of the bay, the mudstone series (passing upward into coarser beds) continues, but no evidence as to its age was discovered.

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* By some error the locality is marked on lithos. as Twait Cutting, and was introduced to palaeontologists as Twaite's Cutting (Thomson, 1919, p. 7). As this portion of the country is known as Te Awaite, and the Cutting is always referred to locally as Te Awaite Cutting, it seems best, in view of the fact that little work has been done upon it, to revert to the correct form.

FAUNA FROM THE SEA CLIFFS EAST OF LAKE FERRY, PALLISER BAY.

Zethalia zelandica (H. & J.).
Stiracolpus symmetricus (Hutton).
Maoricolpus proroseus Marwick.
Pelicaria acuminata (Marwick).
Pelicaria cf. *acuminata* (Marwick).
Pelicaria media (Marwick).
Cochlis australis (Hutton).
Cochlis denticulifera (Marwick).
Cochlis cf. *planisuturalis* (Marwick).
Cymatium jobbernsi n. sp.
Austromitra planata (Hutton).
Verconella sp.
Aeneator cf. *marshalli* (Murdoch).
Aeneator imperator n. sp.
Ellicea orbita (Hutton).
Ellicea carinata Powell.
Austrofusus claviculus n. sp.
Austrofusus incertus n. sp.
Cominula hamiltoni (Hutton).
Zephos onokeana n. sp.
Poirieria zelandica (Q. & G.).
Zeatrophon n. sp. aff. *waitemataensis*.
Bonellitia fundata Marwick.
Zemitrella n. sp. aff. *pseudo-marginata*.
Pachymelon callaghani King.
Alcithoe exigua Marwick.
Alcithoe subgracilis Marwick.
Iredalina finlayi n. sp.
Baryspira mucronata (Sowerby).
Awateria retiolata n. sp.
Awateria n. subsp.
Bathytoma murdochi Finlay.
Austrodrillia alpha n. sp.
Austrodrillia beta n. sp.
Austrodrillia gamma n. sp.
Splendrillia sp.
Insolentia solitaria n. sp.
Filodrillia studiosorum n. sp.
Comitas onokeana n. sp.
Dentalium cf. *nanum* (Hutton).
Neilo australis (Q. & G.).
Chlamys radiata (Hutton).
Chlamys delicatula (Hutton).
Pleuromeris zelandica (Desh.).
Paradione multistriata (Sowerby).
Marama murdochi Marwick.
Nemocardium pulchellum (Gray).

FAUNA FROM THE RUAKOKOPATUNA VALLEY, 1½ TO 3 MILES ABOVE THE JUNCTION OF THE RUAKOKOPATUNA AND MAKARA STREAMS, SOUTH WAIRARAPA.

Micrelenchus tenebrosus (A. Adams).
Antisolarium egenum (Gould).
Zethalia zelandica (H. & J.).
Zeacumantus lutulentus (Kiener).
Zeacolpus cf. *vittatus* (Hutton).
Stiracolpus symmetricus (Hutton).
Zegalerus tenuis (Lesson).
Zeacrypta monoxyla (Lesson).
Cochlis cf. *planisuturalis* Marwick.
Odostomia georgiana Hutton.
Coluzea espinosa Finlay.
Aeneator cf. *marshalli* Murdoch.
Austrofusus cf. *glans* (Bolten).
Poirieria zelandica (Q. & G.).
Xymene cf. *drewi* (Hutton).
Alcithoe gracilis (Swainson).
Alcithoe swainsoni Marwick.
Baryspira mucronata (Sowerby).
Awateria retiolata n. sp.
Austrodrillia cf. *gamma* n. sp.
Phenatoma novae-zelandiae (Reeve).
Acteon praestitus Finlay.
Dentalium nanum Hutton.
Nucula castanea (A. Adams).
Nuculana bellula (A. Adams).
Glycymeris shrimptoni Marwick.
Chlamys sp.
Talabrica senecta Powell.
Pleuromeris zelandica (Desh.).
Venericardia purpurata (Deshayes).
Venericardia marshalli Marwick.
Divaricella cf. *notocenica* n. sp.
Myllitella finlayi Marwick.
Scalpomactra scalpellum (Reeve).
Paradione multistriata (Sowerby).
Tawera spissa (Deshayes).
Bassina parva Marwick.
Chione stutchburyi (Gray).
Gari lineolata (Gray).
Aloidis zelandica (Q. & G.).
Myadora kai-iwiensis Powell.

Fauna from the Junction of the Ruakokopatuna and Makara Streams, South Wairarapa.

Parvacmea nukumaruensis Oliver.
Micrelenchus tenebrosus (A. Adams).
Venustas hodgei (Hutton).
Antisolarium egenum (Gould).
Zethalia zelandica (H. & J.).
Haurakia (?) sp.
Lironoba charassa Finlay.
Estea sp.
Zeacumantus lutulentus (Kiener).
Zeacolpus cf. *vittatus* (Hutton).
Stiracolpus symmetricus (Hutton).
Maoricolpus roseus (Q. & G.).
Struthiolaria tasmani n. sp.
Pelicaria acuminata (Marwick).
Pelicaria cf. *acuminata* (Marwick).
Pelicaria media (Marwick).
Pelicaria cf. *fossa* (Marwick).
Pelicaria rugosa (Marwick).
Zegalerus crater Finlay.
Zegalerus tenuis (Lesson).
Zeacrypta monoxyla (Lesson).
Tanea zelandica (Q. & G.).
Cochlis australis (Hutton).
Cochlis cf. *planisuturalis* (Marwick).
Syrnola sp.
Odostomia georgiana Hutton.
Turbonilla sp.
Coluzea espinosa Finlay.
Verconella accipitris Finlay.
Verconella rex Finlay.
Aeneator imperator n. sp.
Aeneator cf. *marshalli* (Murdoch).
Austrofusus cottoni n. sp.
Austrofusus cf. *glans* (Bolten).
Austrofusus pagoda Finlay.
Austrofusus marshalli n. sp.
Austrofusus sp.
Eucominia excoriata Finlay.
Cominula hamiltoni (Hutton).
Zephos onokeana n. sp.
Poirieria zelandica (Q. & G.).
Zeatrophon ambiguus (Phil.).
Xymene plebejus (Hutton).
Xymene drewi (Hutton).
Lepsithais cf. *lacunosa* (Brug.).
Bonellitia fundata Marwick.
Pachymelon bartrumi n. sp.
Alcithoe exigua Marwick.
Alcithoe cf. *swainsoni* Marwick.
Alcithoe gracilis (Swainson).
Alcithoe subgracilis Marwick.
Alcithoe gatesi Marwick.
Baryspira depressa (Sowerby).
Baryspira mucronata (Sowerby).
Austrodrillia cf. *alpha* n. sp.
Austrodrillia beta n. sp.
Austrodrillia cf. *gamma* n. sp.
Bathytoma murdochi Finlay.
Filodrillia studiosorum n. sp.
Phenatoma zelandica (Smith).
Phenatoma novaezelandiae (Reeve).
Pervicacia tristis (Deshayes).
Acteon praestitus Finlay.
Dentalium nanum Hutton.
Dentalium cf. *zelandicum* Sowerby.
Cadulus sp.
Nucula castanea (A. Adams).
Nuculana bellula (A. Adams).
Anomia trigonopsis (Hutton).
Glycymeris cf. *laticostata* (Q. & G.).
Glycymeris shrimptoni Marwick.
Glycymeris modesta (Angas).
Limopsis zelandica Hutton.
Perrierina bensoni n. sp.
Aulacomya maoriana (Iredale).
Modiolus areolatus (Gould).
Chlamys radiata (Hutton).
Chlamys delicatula (Hutton).
Limatula maoria Finlay.
Ostrea sp.
Talabrica senecta Powell.
Pleuromeris zelandica (Desh.).
Venericardia cf. *purpurata* (Desh.).
Pteromyrtaea dispar (Hutton).
Divaricella notocenica n. sp.
Myllitella finlayi Marwick.
Macoma spenceri Suter.
Barytellina anomalodonta Finlay.
Amphidesma subtriangulata (Gray).
Paphies cf. *australis* (Gmelin).
Mactra ovata (Gray).
Longimactra elongata (Q. & G.).
Zenatia acinaces (Q. & G.).
Dosinia greyi Zittel.
Dosinia subrosea (Gray).
Dosinia cf. *kaawaensis* Marwick.
Paradione multistriata (Sowerby).
Tawera subsulcata (Suter).
Tawera assimilis (Hutton).
Bassina parva Marwick.
Bassina cf. *yatei* (Gray).
Chione cf. *stutchburyi* (Gray).
Chione crassitesta Finlay.
Paphirus largillierti (Philippi).
Nemocardium pulchellum (Gray).
Gari stangeri (Gray).
Offadesma angasi (C. & F.).
Myadora cf. *striata* (Q. & G.).
Myadora cf. *antipodum* E. A. Smith.

Fauna from Te Awaite Cutting, East Coast Road, 5 miles south-east of Martinborough.

Stiracolpus symmetricus (Hutton).
Zeacolpus vittatus (Hutton).
Pelicaria acuminata (Marwick).
Pelicaria cf. *acuminata* (Marwick).
Pelicaria rugosa (Marwick).
Verconella accipitris Finlay.
Aeneator imperator n. sp.
Buccinulum sp.
Poirieria zelandica (Q. & G.).
Alcithoe subgracilis Marwick.
Baryspira mucronata (Sowerby).
Comitas onokeana n. sp.
Bathytoma murdochi Finlay.
Chlamys delicatula (Hutton).
Tawera subsulcata (Suter).

Fauna from the Junction of the Gladstone, Martinborough and Hinakura Roads, South Wairarapa.

Stiracolpus symmetricus (Hutton).
Zeacolpus sp.
Struthiolaria tasmani n. sp.
Pelicaria fossa (Marwick).
Pelicaria media (Marwick).
Austrofusus sp.
Xymene plebejus (Hutton).
Poirieria zelandica (Q. & G.).
Aloithoe subgracilis Marwick.
Baryspira mucronata (Sowerby).
Austrodrillia cf. *gamma* n. sp.
Glycymeris modesta (Angas).
Pteromyrtea dispar (Hutton).
Zemysia zelandica (Gray).
Paradione multistriata (Sowerby).
Bassina parva Marwick.
Panope zelandica (Q. & G.).

The lists of fossils from the Ruakokopatuna Valley, published by Waghorn (1927), agree very well with those described herein from localities of Nukumaruan age. *Glycymeris waipipiensis* Marwick is the only fossil which might indicate a slightly earlier age, and as Waghorn's estimate of a Waitotaran age was based purely on a 55 percentage of Recent species, it seems very probable that his faunas would be better correlated with those listed herein from Nukumaruan localities. That beds of Waitotaran age are present in the Southern Wairarapa seems undoubted, but in all other localities in the area they have proved, as yet, unfossiliferous, and bearing in mind the close relationship of the Ruakokopatuna fossils with those from Nukumaruan localities very near at hand, it seems best to regard his faunas as equivalent to those at the Junction of the Ruakokopatuna and Makara Streams and at Whangaimona, Palliser Bay.

Acknowledgments:

In collecting the material upon which this paper is based, the writer has, from time to time, been ably assisted by several kind friends. To them, one and all, his thanks are here extended for their efforts on his behalf. In addition, the writer here expresses his gratitude to Mr Colin Campbell and Mr K. J. McNaught, whose enthusiasm has led them to forward several excellent collections from Palliser Bay and Ruakokopatuna respectively. To Dr Marwick, of the Geological Survey, the writer is indebted also for much invaluable advice and helpful criticism.

The *Holotypes* of all species described in this paper have been presented to the collection of the New Zealand Geological Survey.

SYSTEMATIC PALAEONTOLOGY.

Family Rissoidae.

The rissoids obtained from the cleanings of larger shells are for the most part worn and corroded, so that details of sculpture are completely effaced. *Haurakia* sp. is but doubtfully referable to the genus. *Estea* sp. may be *E. rugosa* (Hutton).

Genus Zeacolpus Finlay, 1926.

Zeacolpus n. sp.

Though no specimens sufficiently well preserved to warrant description were obtained, comparison with other material indicates that the Palliser Bay species is very close to a new species from Mount Harris, South Canterbury, and should be re-examined when the southern shell is described.

Locality: Putangirua Creek, Palliser Bay.

Genus Struthiolaria Lamarck, 1816.

Struthiolaria tasmani n. sp. (Fig. 30).

A new species of *Struthiolaria* intermediate between *S. papulosa* and *S. frazeri* though much nearer to *papulosa.* A shell of this type was figured by Marwick (1924; Pl. 12, Fig. 4) from N.Z.G.S. Locality 1094, Mangatahi River, Hawke's Bay. As the specimens from the Southern Wairarapa are all damaged the shell already figured is taken as type.*

Localities: Junction of Ruakokopatuna and Makara Streams; Junction of the Gladstone, Hinakura, and Martinborough Roads.

Genus Pelicaria Gray, 1857.

Pelicaria acuminata (Marwick). *Trans. N.Z. Inst.*, vol. 55, 1924, p. 185 (Fig. 28).

Many specimens from Te Awaite Cutting have the spire lower than the typical *acuminata,* and the topmost spiral cord, even in the early stages, is distinctly nodulous. The spiral threads on the base vary in number and in strength, being usually fewer and stronger the more nearly the shell approaches *acuminata.* They thus appear to grade towards *P. media* (Marwick). Another variety of *P. acuminata* occurs at the Junction of the Ruakokopatuna and Makara Streams. It has the same tendency towards a lowering of the spire, but the cingulae tend to become much weaker, and nodules do not appear on the uppermost spiral cord. Also in place of heavy spiral cingulae the ornamentation, on the earlier whorls especially, takes the form of fine spiral cords with equal interstices. Thus these shells appear to grade more towards *P. fossa* (Marwick) than to *P. media.* Probably the whole assemblage represents a hybrid swarm.

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* Since the above account was written Mr K. J. McNaught has re-collected from the Junction of the Ruakokopatuna and Makara Streams, and has obtained several unbroken specimens, one of which is figured here (Fig. 30).

In addition to the normal high-spired *acuminata,* several specimens of a low-spired variety were obtained from the cliffs between Lake Ferry and Whangaimona, Palliser Bay.

Genus COCHLIS Bolten, 1798.

Cochlis australis (Hutton). *Journ. d. Conch.,* vol. 26, 1878, p. 23.

The specimens obtained from the cliffs between Lake Ferry and Whangaimona, Palliser Bay, show considerable variation both in the size of the shell and in the size and shape of the parietal callus.

Genus CYMATIUM Bolten, 1798.

Cymatium jobbernsi n. sp. (Fig. 1).

Shell of medium size, fusiform, of more than 5 whorls. Protoconch lost. Sculpture of regular axial ribs, about 14 per whorl, reaching from suture to suture, and continuing on the body-whorl though absent on the base. Interrupted at intervals by strong varices, 3 in two whorls. The shape of the shell distorted by inflation after each varix. Spiral cords prominent, two very strong and producing, where they cross the axials, two rows of tubercles, one on the shoulder angle and one midway between the shoulder angle and the lower suture. On the penultimate whorl a third row of tubercles appears below them. Normally three minor spiral cords present between the rows of tubercles. Minor spirals only on the shoulder. Suture waved, lightly incised. Spire considerably higher than the aperture with canal. Inner lip thick, covering the spirals on most of the base. Columella lightly concave. Fasciole indistinct.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 37 mm. Diameter 20 mm.

This shell is of considerable interest, in that its relationships are with Oamaruian rather than with Recent species. The type was the only specimen obtained from Palliser Bay, but a shell from Hundalee Conglomerate, Billy's Creek, Conway River, South Marlborough, in the writer's collection is evidently conspecific.

Genus AENEATOR Finlay, 1926.

Aeneator imperator n. sp. (Fig. 3).

Shell large, slender, fusiform, sculpture consisting of axial ribs, 12 per whorl, not extending much on to the shoulder, and tending to become obsolete on the body-whorl. Interspaces wider than the ribs. On the spire four flattened spiral cingulae override the axials below the shoulder angle and one above, single secondary threads appearing between them on the fifth whorl. This sculpture of alternate strong and weak spiral cords becomes characteristic of the later whorls, though occasionally two thin spirals appear instead of one. The whole crossed by faint lines of growth. Spire high, 1¼ times the height of the aperture without canal. Whorls 7, convex, lightly shouldered, ascending slightly towards the suture. Aperture oval, produced below into a long unnotched canal inclined to the left.

Columella slightly oblique, produced to the left below. Inner lip thin, the spirals showing through above.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 48 mm. Diameter 20 mm.

The *holotype* is not quite full grown. This species is probably related, though not closely, to *A. thomsoni* (Marwick).

Genus ELLICEA Finlay, 1928.

Ellicea carinata Powell. *Trans. N.Z. Inst.*, vol. 60, 1929, p. 90, and **Ellicea orbita** (Hutton). *Trans. N.Z. Inst.*, vol. 17, 1885, p. 326.

Both species occur plentifully in the Cliffs east of Lake Ferry, Palliser Bay, together with several intermediate forms suggestive of a hybrid swarm.

Genus AUSTROFUSUS Kobelt, 1879.

Austrofusus claviculus n. sp. (Fig. 5).

Shell of moderate size, fusiform, solid. Protoconch worn. Sculpture consisting on the third whorl of prominent, rounded, axial ribs inclined steeply to the left, becoming vertical on the fourth whorl, and persisting to the suture above and below. On the later whorls the axials become accentuated, though not nodular, on the shoulder, and incline to the left at an angle of 30 degrees between the shoulder and upper suture. The interspaces about the same width as the ribs, which tend to become obsolete on the body-whorl. On the fourth whorl two fine spiral cords surmounting the axials appear below the shoulder, a third appearing below them on the fifth, the number increasing to five on the sixth whorl. Below the line of suture on the body-whorl, where the axial ribs have become obsolete, the spiral cords, to the number of nine, become very strong, showing through the inner lip above. Spire turreted, the same height as the aperture with canal. Whorls 7; shoulder broad, convex, ascending strongly to the suture; below the angle the later whorls contract, though the earlier are vertical; suture impressed, slightly waved. Aperture oval, angled above and at the carina, produced below into a short, slightly oblique canal. Outer lip sharp. Columella vertical, turned to the left below. Inner lip spreading narrowly as a thin callus over the body, showing near the top traces of the spirals beneath, and margined from the line of suture to the fasciole by a deep, narrow channel.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 41 mm. Diameter 19 mm.

This species most resembles *A. pagoda* Finlay = *(Siphonalia turrita* Suter), from which it differs in the absence from the spire of sharp nodules where the axial ribs cross the shoulder, the directing forward of the axials above the shoulder, and in the relative subordination of the spirals, especially above the shoulder, which is distinctly rounded, and not sharp as in *pagoda.* On the base the spiral cords are more numerous, wider, and closer together than on topotypes of *pagoda,* and the anterior canal is less bent to the left. On *pagoda,* also, the inner lip is not margined by a deep, narrow channel.

Austrofusus incertus n. sp. (Fig. 4).

Shell of medium size, strong, fusiform. Protoconch, and indeed much of the type specimen, spoiled by solution. Sculpture of axial ribs, about 14 per whorl, only faint above the shoulder angle, and not extending on to the base. Spiral sculpture of weak cords on the shoulder, one situated at about ⅔ below the suture somewhat stronger. Below the shoulder angle three strong cords surmount the axials and produce nodules. These are somewhat accentuated on the type by solution of the surrounding portions. The base and neck with strong spirals 1½ times their width apart. Spire 1¼ times the height of the aperture with canal. Whorls 6 on broken holotype, strongly angled. Suture waved. Columella vertical, excavated above, strongly bent to the left below. Inner lip thick, spreading well over the body-whorl. Fasciole prominent.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 30 mm. Diameter 17 mm.

This species is of the "glans" type, but is distinctive in its sculpture, high spire, and the strong excavation and twisting of the columella.

Austrofusus cottoni n. sp. (Fig. 21).

Shell of medium size, turreted strong. Sculpture of the post-embryonic whorls consisting of well-marked axial ribs appearing after the 2¾ whorls of the protoconch, and growing regularly stronger to the penultimate whorl, interspaces about the same width as the ribs. After the fifth whorl the ribs are only weakly developed above the shoulder, and on the last quarter turn of the body-whorl they tend to become obsolete. On the fourth whorl two spiral cords appear at the shoulder, a third appearing below them on the fifth whorl, two somewhat finer cords also showing above the shoulder. On all the later whorls the two original cords remain the strongest, though a strong cord, and later two strong cords, appear margining the suture below. On the penultimate whorl are 8 spirals and 14 axial ribs. On the base of the shell axials persist feebly, but the spiral sculpture becomes dominant as 7 heavy ridges, somewhat narrower than the interspaces. Spire turreted, very high, 1¼ times the height of the aperture. Protoconch smooth, of 2¾ whorls. Whorls 8½; shoulder distinct, midway between the sutures. Sutures waved, due to the axials. Aperture sub-oval, strongly angled above and at the periphery, channelled above and produced below into a strong anterior canal turned to the left. Outer lip probably sharp. Columella vertical, turned to the left below. Inner lip thin, but not showing any trace of axials beneath.

Locality: Junction of Ruakokopatuna and Makara Streams, South Wairarapa.

Dimensions: Height 30 mm. Diameter 14 mm.

This species differs from all other Austrofusids in the abnormal height of the spire.

Austrofusus marshalli n. sp. (Fig. 29).

Shell of moderate size, strong, fusiform. Protoconch worn on all available specimens. Sculpture, early consisting of high axial ribs inclined steeply to the left, later attaining the vertical and becoming obsolete on the last half of the body-whorl. Interspaces a little wider than the ribs, which reach the suture above and below, though considerably weaker above the shoulder. Spiral sculpture of three strong cords and one fine thread above the shoulder, surmounting the axials in weak nodules, and two cords with numerous threads present below the suture. A further cord present on the shoulder angle exhibits a waved appearance between the nodules where it crosses the axial ribs. Base and neck with 8 heavy spiral cinguli. Spire the same height as the aperture with canal. Whorls 7½; shoulder steep, lightly concave; suture waved, due to the axials. Aperture oval, rather narrow for the genus, produced below into a short, strong canal. Inner lip moderately thick, but not obliterating the upper axial ribs. Columella vertical, fasciole prominent.

Locality: Junction of the Ruakokopatuna and Makara Streams, S. Wairarapa.

Dimensions: Height 42 mm. Breadth 19 mm.

The heavy spirals on the base and neck of this shell, together with the formation of the inner lip and fasciole, give a strong resemblance to *A. claviculus* n. sp. From this, however, it is immediately distinguished by the shape of the shoulder and spire. A certain resemblance between *A. marshalli* and *A. cottoni* quite possibly indicates a common ancestry.

Austrofusids of the " glans-taitae " type occur in almost bewildering variety at the South Wairarapa localities. Some of the more prominent types have been separated above, but until more extensive collections are available it seems best to refrain from further " splitting."

Subgenus NEOCOLA Finlay, 1926.

Austrofusus (Neocola) marwicki n. sp. (Fig. 15).

Shell small, bucciniform, solid. Sculpture consisting, on the two earliest adult whorls, of axial ribs contracting on the later whorls to sharp nodules on the shoulder angle, 12 on the penultimate whorl. Strong, subequal spiral cords cover all the adult whorls and the base, where one is sharply nodulous, and forms a well-defined keel margined above by another slightly nodulous spiral and below by a smooth and then a third accentuated nodulous cord. The whole crossed by well-marked lines of growth. Spire about the same height as the aperture with canal. Adult whorls 5, broad, with a long sloping shoulder. Suture impressed, somewhat waved. Base strongly contracted, and twisted into a prominent high fasciole. Aperture narrow, oblique, contracting to a short recurved canal. Outer lip thick, inner lip spreading well over the base. Columella stout, vertical, strongly twisted below.

Locality: Mouth of Putangirua Creek, Palliser Bay.

Dimensions: Height 23 mm. Diameter 12 mm.

This shell most closely resembles *Austrofusus (Neocola) alpha* Finlay from Clifden Band 4b, from which it may be distinguished by the earlier substitution of nodulous for axial sculpture, weaker spiral cords, and the presence, on the base, of the nodulous keel with the bordering strong, nodulous spirals. From topotypes of *A. (Neocola) beta* Finlay it differs in having nodules rather than raised ribs, steeper and longer shoulder, giving a less turreted appearance and the nodulous basal keel.

Genus ZEPHOS Finlay, 1926.

Zephos onokeana n. sp. (Fig. 14).

Shell of medium size, turreted, solid. Sculpture consisting of heavy axial ribs, about the same width as the interspaces, showing no trace of obsolescence even on the body-whorl, where there are 14 ribs. The whole crossed by prominent spiral threads, 3 above and 4 below the shoulder on the penultimate whorl, becoming more distant and a little stronger on the base. Spire turreted, about the same height as the aperture with canal. Protoconch badly worn. Whorls 6; shoulder broad, almost angular. Suture waved, margined below by an area free of spiral threads. Aperture oval, channelled above and produced below into a short, very oblique, recurved canal. Outer lip thick, spreading a little over the body-whorl. Fasciole prominent, defined above by a thin, sharp ridge.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 21 mm. Diameter 11 mm.

This species differs from *Z. purchasi* (Suter) in its smaller size, more angular shoulder and stronger axial ribs on the body-whorl. There are only 14 axials on the body-whorl instead of 20 as in *purchasi.*

Topotypes show some variation in the height of the spire. Though more than 200 specimens were examined, not one unworn protoconch was obtained.

Genus COMINISTA Finlay, 1926.

Cominista putangirua n. sp (Fig. 13).

Shell of medium size, fusiform, solid. Sculpture of strong nodules upon the shoulder, 10 on the penultimate whorl. The body-whorl crossed by 10 narrow, distant spiral threads. Growth-lines apparent on the penultimate and body-whorls. Spire conic, much lower than the aperture. Whorls 4 without the protoconch; shoulder low, broad, situated at about ⅓ of the distance between the sutures on the spire. Suture slightly impressed. Columella vertical, turned to the left below. Inner lip spreading well over the body-whorl. Fasciole strong, paralleled above by a prominent ridge.

Locality: Mouth of Putangirua Creek, Palliser Bay.

Dimensions: Height 25 mm. Diameter 14½ mm.

The unique holotype is unfortunately worn, and details of the earlier sculpture are erased. This species differs from other "*Coministas*" in its abnormal breadth and very depressed spire.

Genus POIRIERIA Jousseaume, 1879.

Poirieria zelandica (Q. & G.). *Voy. Astrolabe,* vol. 2, 1833, p. 529.

The specimens obtained from Palliser Bay were all very large, thick shells.

Genus ZEATROPHON Finlay, 1926.

Zeatrophon n. sp. aff. **waitemataensis** Powell and Bartrum. *Trans. N.Z. Inst.,* vol. 60, 1929, p. 436.

A shell similar to *Z. waitemataensis,* but differing in axial sculpture, having more numerous and weaker axial ribs (15 on the body-whorl), all inclined steeply to the left below the shoulder angle and directed forward at an angle of 50° on the shoulder. They also persist on to the neck of the shell, though this may be only a juvenile feature.

Genus ZEMITRELLA Finlay, 1926.

Zemitrella n. sp. aff. **pseudomarginata** (Suter). *Proc. Mal. Soc.,* vol. 8, 1908, p. 179.

The single specimen obtained is too broken to warrant description.

Genus ANTIZAFRA Finlay, 1926.

Antizafra wairarapa n. sp. (Fig. 10).

Shell small, bucciniform. Protoconch smooth, of 2½ whorls. Axial sculpture of numerous low, smooth ribs, about their own width apart, on all the adult whorls. On the first adult whorl several spiral cords cross the axials, but die out on the second adult whorl. A narrow channel margins the suture below. The base and neck covered by low, flat spiral cords. Aperture semilunar, produced below into a notched recurved canal; outer lip thin; inner lip not pronounced. Columella vertical, bent to the left below.

Locality: Hurupi Creek, Palliser Bay.

Dimensions: Height 4 mm. Diameter 2 mm.

Genus PACHYMELON Marwick, 1926.

Pachymelon bartrumi n. sp. (Fig. 32).

Shell large, solid, broadly fusiform. Protoconch large, blunt, of two smooth whorls. Sculpture of low, somewhat obsolete longitudinal ribs, rather stronger below the shoulder, on the first two spire-whorls; after which the shell is devoid of ornament though crossed by numerous well-marked growth-lines. The obsolescence of the axial ribs is somewhat variable on different specimens, one paratype showing them persisting for almost three complete whorls. Spire low, about one-half the height of the aperture. Whorls 6½, convex, lightly shouldered. Columella with five plaits, the uppermost weakest. Inner lip spreading as a glaze well over the body-whorl. Anterior notch moderately deep, fasciole inconspicuous.

Locality: Junction of the Ruakokopatuna and Makara Streams, S. Wairarapa.

Dimensions: Height 90 mm. Breadth (estimated) 45 mm.

A specimen from Tinui, Wairarapa, now in the collection of the N.Z. Geological Survey may possibly be this species.

Genus ALCITHOE H. & A. Adams, 1858.

Alcithoe swainsoni Marwick. *Trans. N.Z. Inst.*, vol. 56, 1926, p. 294.

The Wairarapa fossils are much more like Recent shells than the type which is from Kai-Iwi. They are devoid of tubercles on the body-whorl.

Genus IREDALINA Finlay, 1926.

Iredalina finlayi n. sp (Figs. 23, 24, 25).

Shell large, fusiform, smooth, with a glazed, shining surface. Apex lost on holotype, projecting as a long spike on paratypes. Sculpture, a few barely discernible spiral lirae on the base, beginning at the lower half of the aperture, otherwise smooth and glossy. Fine, close lines of growth, slightly retracted to the suture above, apparent on unrubbed portions of the shell. Spire a little lower than the aperture. Whorls convex, regularly increasing both in size and convexity. Aperture long, oblique, produced below into a long anterior canal. Outer lip thin, slightly retracted above, broken below. Inner lip smooth. Columella vertical, completely devoid of plaits, but with a light tubercle low down. Juvenile paratypes exhibit the trace of a single plait low down on the columella.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 88 mm. Diameter 36 mm.

The caricelloid spike forming the apex in juvenile paratypes has the shelly material worn so that comparisons based upon it may be erroneous; but it recalls the similar appearance of several South American Volutes, e.g., *Zidona angulata* (Solander). The subobsolete columella plait in juveniles is a feature of great importance, showing descent from a stock in which this feature was developed. Dr Finlay, to whom these shells were submitted for comparison with his *Iredalina mirabilis* (see Finlay, 1926C), has kindly commented as follows upon this juvenile plait: " This (plait) is not at all like the *Lyria-Eosephaea-Plejona* plait which runs through a large number of Volute genera. . . . but is more like a fusinid ridge such as is seen in *Fasciolaria* derivatives, *Euthriofusus* and the *Buccinulum* series." In comparison with *I. mirabilis* he notes: " The sutural sinus, polish and general habit are the same, but the spire is relatively lower, that of *mirabilis* having a much more unrolled appearance. The whorls are also less clasping, the subsutural concave space in *mirabilis* being wider and more striking. The columella seems identical." In connection with the spiral sculpture on the base he notes: " I have not mentioned this as one of the distinctions from *mirabilis* (though it may be), as the surface of the Genotype is mostly chalky and rubbed on the base. However, there are a few polished patches left on the area mentioned, and on none of these can I detect any spirals, so it may well be that this is a feature of your n. sp."

It would seem that *I. finlayi* is very close to *I. mirabilis,* and is directly ancestral. Its presence in the Tertiary shows that the genus is a true member of the New Zealand fauna, and has been here since at least Nukumaruan times.

Genus COMITAS Finlay, 1926.

Comitas abnormis n. sp. (Fig. 17).

Shell of medium size, strong, fusiform. Sculpture of short axial ribs (almost nodules) on and just below the shoulder angle. Weak spiral threads cover most of the spire-whorls, and are stronger below the shoulder angle. The base is also covered with fine to medium spiral riblets. Protoconch broken on holotype, smooth on a paratype, later developing a median spiral cord, which later still becomes nodulous. Whorls 6 on the broken type; shoulder long, steep, ascending strongly to the waved suture. Aperture oblique, oval, contracting below; outer lip thin; inner lip spreading thinly over the base.

Locality: Mouth of Putangirua Creek, Palliser Bay.

Dimensions: Height 25 mm. Diameter 11 mm.

Comitas onokeana n. sp. (Fig. 16).

Shell of medium size, fairly thick, strong, fusiform. Sculpture: Protoconch of 1¾ whorls, smooth on the first 1¼ whorls, then developing a strong median spiral cord, below which appear somewhat later two fine spiral lirae. After half a whorl, nodules develop on the median cord, which then becomes obsolete, the nodules becoming elongate and reaching to the suture below, but not passing much over the shoulder. The two spiral lirae persist and become stronger, overriding the axial ribs, and increase in number to four on the fifth whorl. The base of the shell is covered with broad, flat spirals. The most prominent sculpture consists of heavy axial ribs (after the second whorl) inclined steeply to the left, and passing to the suture below, but not above the shoulder. Spire turreted, high, 1¼ times the height of the aperture with canal. Whorls 7½; shoulder concave, well developed, accentuated by the axials, halfway between the sutures. Suture simple, not impressed. Aperture oval, produced below into a long canal turned to the left, and then becoming vertical; posterior sinus strong. Outer lip sharp. Columella vertical, slightly bent to the left below. Inner lip thin, bounded by an incised line.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 30 mm. Diameter 12 mm.

This species may easily be distinguished from *C. oamarutica* (Suter) by its more slender form and the persistence of the axial ribs. From *C. fusiformis* (Hutton) it differs in its more slender form, higher spire, and less convex whorls.

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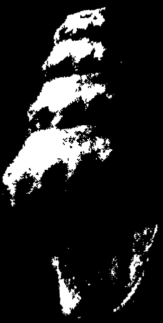

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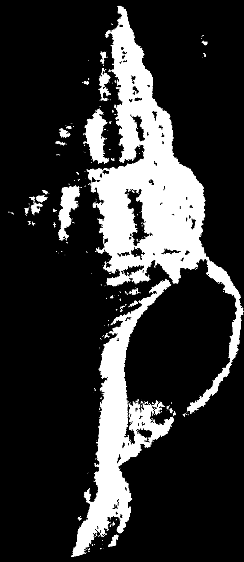

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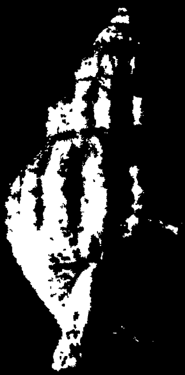

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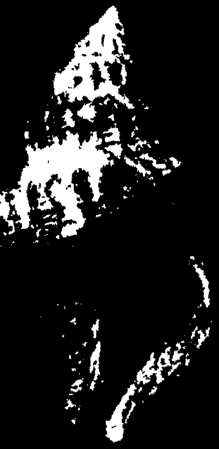

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FIG. 1.—*Cymatium jobbernsi* n. sp.; Holotype: 37 mm. × 20 mm.
FIG. 2.—*Comitas imperfecta* n. sp.; Holotype; 25 mm. × 14 mm.
FIG. 3.—*Aeneator imperator* n. sp.; Holotype; 48 mm. × 20 mm.
FIG. 4.—*Austrofusus incertus* n. sp.; Holotype: 30 mm. × 17 mm.
FIG. 5.—*Austrofusus olaviculus* n. sp.; Holotype; 41 mm. × 19 mm.

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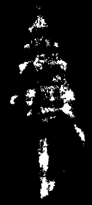

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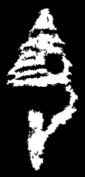

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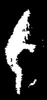

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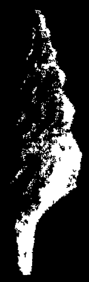

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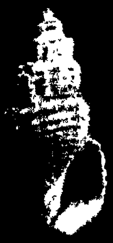

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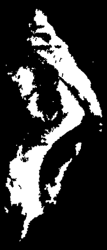
Fig. 6.—*Austrodrillia alpha* n. sp.; Holotype; 12 mm. × 4½ mm.
Fig. 7.—*Austrodrillia beta* n. sp.; Holotype; 12 mm. × 4½ mm.
Fig. 8.—*Austrodrillia gamma* n. sp.; Holotype; 10 mm. × 4 mm.
Fig. 9.—*Filodrillia studiosorum* n. sp.; Holotype; 8 mm. × 4 mm.
Fig. 10.—*Antizafra wairarapa* n. sp.; Holotype; 4 mm. × 2 mm.
Fig. 11.—*Insolentia solitaria* n. sp.; Holotype; 13 mm. × 5 mm.
Fig. 12.—*Awateria retiolata* n. sp.; Holotype; 10 mm. × 4½ mm.



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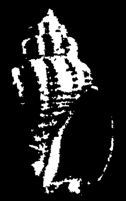

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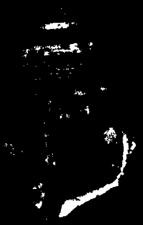

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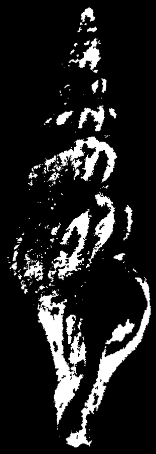

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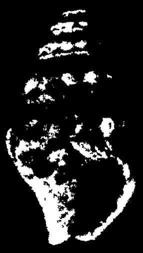

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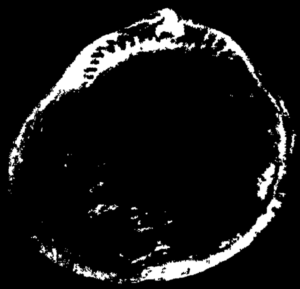

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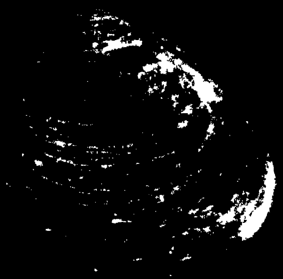

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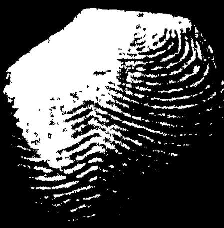
FIG. 13.—*Cominista putangirua* n. sp.; Holotype; 25 mm. × 14½ mm.
FIG. 14.—*Zephos onokeana* n. sp.; Holotype; 21 mm. × 11 mm.
FIG. 15.—*Austrofusus (Neocola) marwicki* n. sp.; Holotype; 23 mm. × 12 mm.
FIG. 16.—*Comitas onokeana* n. sp.; Holotype; 30 mm. × 12 mm.
FIG. 17.—*Comitas abnormis* n. sp.; Holotype; 25 mm. × 11 mm.
FIGS. 18 & 19.—*Limopsis lawsi* n. sp.; Holotype; 27 mm. × 25 mm.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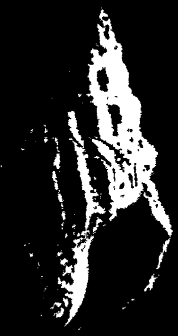
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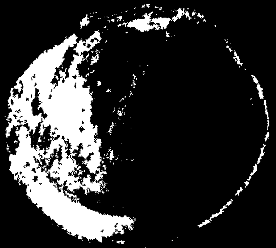
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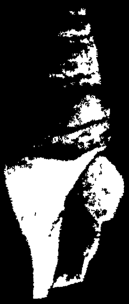
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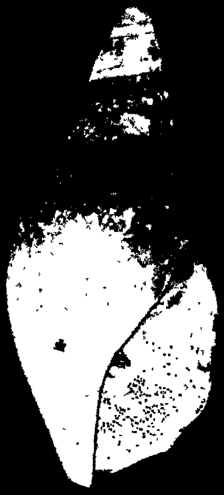
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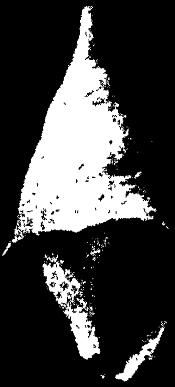
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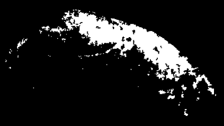
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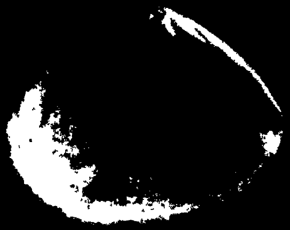
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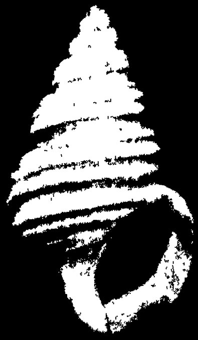
FIGS. 20 & 22.—*Divaricella notocenica* n. sp.; Holotype; 20 mm. × 20 mm
FIG. 21.—*Austrofusus cottoni* n. sp.; Holotype; 30 mm. × 14 mm.
FIG. 23.—*Iredalina finlayi* n. sp.; Paratype; juvenile.
FIG. 24.—*Iredalina finlayi* n. sp.; Holotype; 88 mm. × 36 mm.
FIG. 25.—*Iredalina finlayi* n. sp.; Paratype; showing apex.
FIGS. 26 & 27.—*Barytellina anomalodonta* Finlay; worn specimen.



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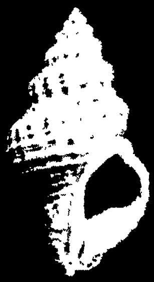

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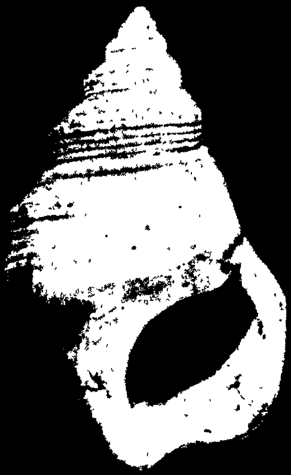

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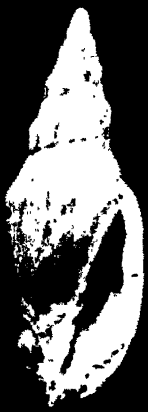

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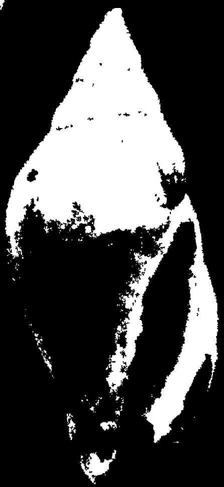

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FIG. 28.—*Pelicaria acuminata* (Marwick); specimen with abnormally high spire.
FIG. 29.—*Austrofusus marshalli* n. sp.: Holotype; 42 mm. × 19 mm.
FIG. 30.—*Struthiolaria tasmani* n. sp.
FIG. 31.—*Alcithoe exigua* Marwick; specimen showing sculpture; 62 mm. × 18 mm.
FIG. 32.—*Pachymelon bartrumi* n. sp.: Holotype; 90 mm. × 45 mm.

Comitas imperfecta n. sp. (Fig. 2).

Shell of medium size, fusiform. Sculpture: Shoulder smooth, axial ribs steeply inclined to the left and crossed by fine spiral lirae below the shoulder angle. Base with spiral lirae only. Shoulder steep, lightly concave, crossed by strongly recurved lines of growth. Spire high. Aperture oval, contracted to a strong anterior canal, and notched above by a deep, broad sinus.

Locality: Marls one mile below Turanganui Gorge, S. Wairarapa.

Dimensions of broken holotype: Height 25 mm. Diameter 14 mm.

This shell is evidently ancestral to *C. onokeana* nov., from which it differs in the greater steepness and lighter concavity of the shoulder and the possession of weaker axial sculpture.

Genus AUSTRODRILLIA Hedley, 1918.

Austrodrillia alpha n. sp. (Fig. 6).

Shell small, fusiform. Protoconch worn. Sculpture commencing as a strong median cord, becoming heavily nodulous after one whorl, the nodules rapidly attaining an elongated form and passing into ribs, strong below, but only faint upon the shoulder, not reaching the suture above and only just attaining it below. Shoulder concave, folded above into a prominent cord which margins the suture below. Spiral threads very faint upon the spire, but strengthening and forming the only sculpture on the base and neck. Spire high, 1¼ times the height of the aperture with canal. Whorls 7½, convex. Aperture oval, slightly oblique, produced below into a broad canal inclined to the left. Outer lip sharp. Columella vertical, turned to the left below. Inner lip well defined.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 12 mm. Diameter 4½ mm.

Austrodrillia beta n. sp. (Fig. 7).

Shell small, slender, fusiform. Protoconch smooth. Sculpture on the first 1½ whorls consisting of a strong median keel, which later becomes nodulous; this condition then persists throughout. Spiral sculpture of three very weak threads on the shoulder angle and a strong spiral cord margining the suture below. The base with one strong spiral cord below the line of suture and numerous weak spiral threads. The whole crossed by faint lines of growth. Whorls 8, very convex. Shoulder concave. Aperture oblique, oval, produced below into a sub-vertical canal. Columella vertical, slightly turned to the left below. Outer lip thin; inner lip well defined.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 12 mm. Diameter 4½ mm.

This species differs from *alpha* in having median nodules on the shoulder in place of axial riblets.

Austrodrillia gamma n. sp. (Fig. 8).

Shell small, fusiform. Protoconch worn. Sculpture of axial ribs, steeply inclined to the left, crossed by two prominent spiral cords on the shoulder angle, with a third near the suture below. The base with spiral sculpture only. Whorls 6 (7 on a paratype), convex. Shoulder concave, mounting to a strong cord below the suture. Aperture slightly oblique, produced anteriorly into a short canal inclined to the left. Outer lip sharp; inner lip thick.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 10 mm. Diameter 4 mm.

This species may be distinguished from *alpha* and *beta* by its stumpier appearance and the two strong spiral cords on the shoulder angle.

Genus INSOLENTIA Finlay, 1926.

Insolentia solitaria n. sp. (Fig. 11).

Shell small, turreted, axially costate and spirally lirate. Protoconch smooth, of 1¼ whorls. Early sculpture of broad, close axial costae, later confined below the shoulder angle and inclined to the left at an angle of 60°. Obsolete on the body-whorl. Spiral lirae covering all the whorls (except protoconch), five above and six below the shoulder angle. Irregular growth-lines cross most of the shell. Whorls 6, angled near the middle, with a high sloping shoulder. Spire gradate, high, twice the height of the aperture. Aperture broken; inner lip smooth, white. Columella vertical.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 13 mm. Diameter 5 mm.

This species is only provisionally placed in *Insolentia,* as the holotype is too incomplete to serve as standard for a new group.

Genus FILODRILLIA Hedley, 1922.

Filodrillia studiosorum n. sp. (Fig. 9).

Shell small, fusiform, with prominent spiral sculpture, consisting of a strong cord on the shoulder with a somewhat weaker cord between it and the lower suture. Strong spiral cords, rather more than their width apart on the base. One weak cord parallel to the suture below. Axial sculpture absent, growth-lines well marked. Whorls 5, carinate; shoulder concave. Spire about the same height as the aperture with canal. Inner lip well defined. Columella vertical, bent to the left below. Fasciole distinct.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 8 mm. Diameter 4 mm.

This shell resembles *F. rupta* Marwick, but it is doubtful if any relationship exists, and its reference to *Filodrillia* must be regarded as provisional.

Named in recognition of the students who collected with me at Palliser Bay, August, 1931.

Genus AWATERIA Suter, 1917.

Awateria retiolata n. sp. (Fig. 12).

Shell small, thin, turreted. Protoconch worn. Sculpture consisting, on the spire-whorls, of axial ribs reaching from the shoulder to the suture and inclined steeply to the left. Interspaces the same width as the ribs. On the spire-whorls four spiral cords, the upper two the stronger, cross the axials below the shoulder, giving a reticulate sculpture to the spire. Shoulder smooth, concave. The body-whorl with spiral sculpture only. The uppermost spiral cord on the shoulder angle is faintly nodulous on the earlier part of the body-whorl as a last suggestion of the previous axial sculpture. Weak growth-lines cover most of the shell, being rather more prominent on the smooth shoulder. Spire high, 1½ times the height of the aperture. Whorls 4½. Aperture subquadrate, strongly channelled below and with a light sinus above. Columella vertical, bent to the left below. Outer lip thin; inner lip well defined.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Dimensions: Height 10 mm. Diameter 4½ mm.

This species and *Awateria* n. subsp. below are but doubtfully referable to the genus. Though they resemble *A. evanida* Suter they do not compare well with *A. streptophora* Suter, the genotype. As a long series has not been available for study, they are, however, left in *Awateria* for the present.

Awateria mollyae n. sp.

Shell similar to *A. retiolata* from which it may be distinguished by a much steeper shoulder, giving the whorls a much less convex appearance, the presence of weak axial ribs on the body-whorl and the fact that only half as many spiral cords appear on the spire-whorls and the upper half of the body-whorl.

Locality: Cliffs east of Lake Ferry, Palliser Bay.

Genus ZEACUMINIA Finlay, 1926.

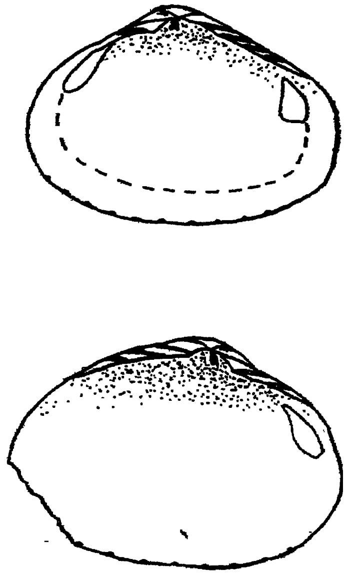
Zeacuminia orycta (Suter). *Trans. N.Z. Inst.*, vol. 45, 1913, p. 295.

The Hurupi specimens closely resemble Target Gully shells.

Genus PERRIERINA Bernard, 1897.

Perrierina bensoni n. sp.

Shell very small, ovate, equivalve, slightly inequilateral. Beaks fairly prominent. Sculpture consisting of microscopic, widely spaced threads. Teeth: Each valve with one bifurcating cardinal beneath the umbo (pointing anteriorly in the left valve, and four straight, horizontal posterior lateral teeth; anterior teeth also straight and horizontal, two in the left and one in the right valve.



Perrierina bensoni. Holotype.

Locality: Junction of the Ruakokopatuna and Makara Streams, South Wairarapa.

Dimensions: Length 2 mm. Height 1·5 mm.

Paratypes of *P. ovata* Marwick, when examined under the microscope, show two cardinal teeth in the left valve and a trace of a central one in the right. These were not noted in his description, and indeed are hardly discernible with a hand lens. It is probable that the type left valve of *P. bensoni* has had the posterior cardinal broken and that the teeth are almost identical with *P. ovata.*

P. taxodonta Bernard I have not seen, but the cardinals exhibited in Suter's drawing (Atlas, Pl. 52, Figs. 12a and b) are very different from those of both *P. ovata* and *P. bensoni.*

Genus PEDALION Huddesford, 1770.

Pedalion fortissimum n. sp.

Shell heavy, large, sub-trigonal, produced ventrally, not very convex. Beaks anterior. Anterior ear not shown on specimen. Structure strongly lamellar, one valve being nearly half an inch thick. Hinge with six, possibly seven, narrow resilifer grooves with much wider interstices (usually twice the width of the furrows).

Locality: Boatshed Creek, south of Putangirua Creek, Palliser Bay.

Dimensions: Length 95 mm. Height 130 mm.

This species differs radically in shape from both *P. oneroaensis* Powell and Bartrum and *P. zelandica* (Hutton) recorded originally from Shrimptons (?) Ngaruroro River, and subsequently discussed by Marshall and Murdoch in their work upon the fossils from Nukumaru. The hinge also cannot be confused with either of the above species.

Pedalion sp. Fragments recorded from Tutamoe Series, N.Z.G.S. localities 1298, 1360, 1794 by Marwick (1931, p. 60) may prove to be this species.

Genus LIMOPSIS Sassi, 1827.

Limopsis lawsi n. sp. (Figs. 18, 19).

Shell of the *zitteli* group, large, inflated; anterior end regularly rounded, posterior produced low down. Beaks not very prominent. Sculpture consisting of irregular growth-ridges with superimposed, fine, concentric striae and faint radial threads. Ligamental area short. Anterior teeth 10, posterior teeth 11.

Locality: Hurupi Creek, Palliser Bay.

Dimensions: Length 27 mm. Height 25 mm.

This species was separated by Dr Finlay some years ago from material in the collection of the Geological Survey, but was not published.

Genus CHLAMYS Roeding, 1798.

Chlamys delicatula (Hutton). *Cat. Tert. Moll.*, 1873, p. 30.

In the Palliser Bay section this species occurs only in the beds at the mouth of the Whangaimona River, i.e., at the base of the fossiliferous beds between Lake Ferry and Whangaimona. See also Thomson (1919, p. 7).

Genus DIVARICELLA v. Martens, 1880.

Divaricella notocenica n. sp. (Figs. 20, 22).

Shell of medium size, subcircular, equivalve, inflated. Sculpture for the first mm. from the umbo of fine, concentric ribs, becoming coarser and waved at 3 mm. from the umbo, later strongly divaricated. The later ribs raised towards the dorsal margin and flattened ventrally. The whole crossed by fine concentric growth-lines and growth-ridges. Ligament sunk, lunule narrow. Right valve with a strong triangular cardinal tooth beneath the umbo, and a deep pit on either side; one very oblique anterior cardinal. Anterior adductor scar long and narrow, posterior oval; pallial line simple.

Locality: Otekaike, Oamaru.

Dimensions: Length 20 mm. Height 20 mm. Thickness (both valves) 10 mm.

As the only specimen from Palliser Bay is closed, a shell from Otekaike, Oamaru, now in the collection of the N.Z. Geological Survey, has, by courtesy of Dr Marwick, been taken as type.

Genus MACOMA Leach, 1819.

Macoma cf. **robini** Finlay. *Trans. N.Z. Inst.*, vol. 55, 1924, p. 474.

The Hurupi shell may, when better material is available, prove to be separable from the Otiake (Hutchinsonian) type. The specimens in the writer's collection are much more attenuated in form, and have a much stronger posterior fold than the true *robini*.

Genus MARAMA Marwick, 1927.

Marama murdochi Marwick. *Trans. N.Z. Inst.*, vol. 57, 1927, p. 601.

This was found only in the higher beds near Lake Ferry.

Genus BASSINA Jukes-Brown, 1914.

Bassina parva Marwick. *Trans. N.Z. Inst.*, vol. 57, 1927, p. 619.

Specimens from the brown sands at the Junction of the Hinakura, Martinborough, and Gladstone Roads are constantly inflated to twice the degree attained by normal shells, as also are most specimens from the Junction of the Ruakokopatuna and Makara Streams.

Genus NEMOCARDIUM Meek, 1876.

Nemocardium pulchellum (Gray). *Dieff. N.Z.*, vol. 2, p. 252.

This, like *Marama murdochi*, was found only in the higher beds near Lake Ferry, Palliser Bay, in the coastal section.

LIST OF NEW SPECIES DESCRIBED IN THIS PAPER.

Struthiolaria tasmani.
Cymatium jobbernsi.
Aeneator imperator.
Austrofusus claviculus.
Austrofusus cottoni.
Austrofusus incertus.
Austrofusus marshalli.
Austrofusus (Neocola) marwicki.
Zephos onokeana.
Cominista putangirua.
Antizafra wairarapa.
Pachymelon bartrumi.
Iredalina finlayi.
Comitas abnormis.
Comitas imperfecta.
Comitas onokeana.
Austrodrillia alpha.
Austrodrillia beta.
Austrodrillia gamma.
Insolentia solitaria.
Filodrillia studiosorum.
Awateria retiolata.
Awateria mollyae.
Perrierina bensoni.
Pedalion fortissimum.
Limopsis lawsi.
Divaricella notocenica.

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The Nature and Mode of Origin of the Motunau Plain, North Canterbury, New Zealand.

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[*Read before the Philosophical Institute of Canterbury, August, 1931; received by Editor, 27th September, 1932; issued separately June, 1933.*]

INTRODUCTION.

THE authors have previously made independent general surveys of shore platforms on considerable lengths of the New Zealand coasts, and in the course of this work the problem of determining definite criteria for the recognition of the mode of origin of these features has constantly arisen. It seemed, therefore, helpful to study conjointly one good shore platform in greater detail, and for this purpose the Motunau Plain on the north-east coast of Canterbury was considered the most suitable.

For a discussion of its mode of origin a study has been made of the following:—

(a) The surface features of the plain.
(b) The nature and distribution of its covering beds.
(c) The planed surface of the basement beds.

A general description of the plain has already been given by one of the present authors (Jobberns, 1928, pp. 543-548); and passing reference to it has been made by Hutton (1877, p. 54); Haast (1879, pp. 366-7); McKay (1881, pp. 108-118; 1883, pp. 74-79); and Speight (1912, pp. 222-4; 1918, pp. 93-105).

A. DESCRIPTION OF THE PLAIN.

(a) The surface features.

This crescent-shaped remnant of a formerly very much more extensive plain is some 12 miles long, and attains a maximum width of about 2 miles in the vicinity of the Motunau River, with a height of 300-350 feet at the rear. Some 1¼ miles off shore, opposite the river mouth, is a remnant of the same plain, namely, Motunau Island, of about 5 acres in summit area.

Most of the plain exhibits the usual regular profile of a shore platform, but there are two striking abnormalities: (1) The absence of defined cliffs at the rear, and (2) the presence of a flat-topped ridge extending along the greater part of the seaward boundary of the plain. As these features might lead the observer to doubt the essentially marine origin of the plain, they were examined more in detail, and fuller reference will be made to them later in this paper.

The plain is dissected by a system of extended and juvenile consequent streams which cross it in deep ravines. The extended streams debouch from deeper gorges in the hills behind the plain, their courses across the latter meandering to some extent and exhibiting flights of terraces which complicate the general topography. They may be responsible, too, for the formation of irregular, superficial fanlike deposits of alluvial material near the inner edge of the plain.

Many of the juvenile consequent streams, however, have simply cut back deep and narrow gullies which do not extend the whole width of the plain, so that they have added nothing to its surface cover.

(b) The covering beds.

As the basement rocks in which the platform has been cut have been dealt with in a general way elsewhere, the present writers are more particularly concerned with a description of the covering beds, which they have traced throughout the district, with the specific purpose of examining them from the point of view of their nature, distribution, and mode of origin. As some variation of type has been found at different points along the plain, it will be convenient to describe the deposits as they are seen in the following characteristic localities, viz.: (1) South of the Motunau River; (2) between the Motunau River and Boundary Creek; (3) the north end of the plain; and (4) Motunau Island. For convenience the localities 1, 2, and 3 will be referred to as the Southern, Middle, and Northern Areas respectively.

1. *The Southern Area.*

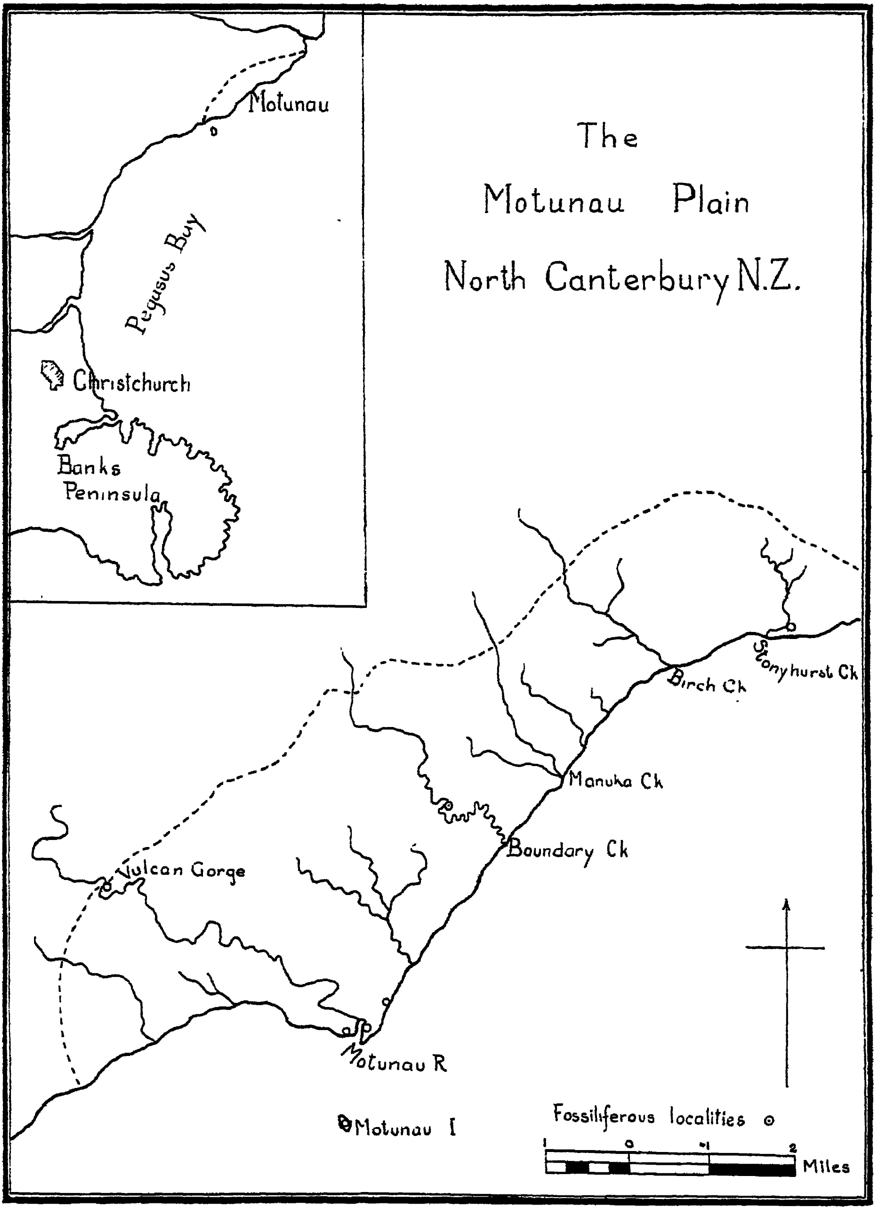
A typical section showing the order of the covering beds has already been noted from the cliffs south-west of the Motunau River (Jobberns, 1928, p. 545). For the purpose of this paper the beds were re-examined in greater detail, and a fuller description is here given. The ascending sequence is as follows:—

(i) Fossiliferous sands and fine greywacke gravel containing large and small irregular fragments of bored sandstone. Such blocks of bored sandstone occur at this horizon only, and were apparently bored in position. The thickness of the fossiliferous layer varies from a few inches up to about 4 feet.

(ii) Marine gravels consisting of well worn, evenly graded greywacke pebbles from ¼ inch to a maximum of 1½ inches diameter. These are sometimes interstratified with sandy bands in varying proportions. The sand is very fine, and was probably derived from the underlying soft sandy rocks in which the platform has been cut. Whatever may be the origin of the upper members of the covering series, these sandy gravels, together with the fossiliferous band below, appear to represent an original marine cover on the cut platform.

(iii) Coarser grained beds consisting almost entirely of pebbles of Amuri limestone, not so evenly graded as the underlying greywacke gravels. The change from the greywacke to the limestone facies is everywhere very abrupt.

(iv) A layer, sometimes attaining a thickness of 6-8 feet of distinctly angular greywacke fragments with occasional angular Amuri limestone pebbles. Taking the pebbles singly, they appear to be of an alluvial type, but their arrangement and grading seems to have taken place under marine conditions. When one considers that the source of supply could have been very close at hand, and that therefore it is likely that they were not rolled to any extent, the angular nature of the pebbles does not seem to be proof of alluvial conditions of deposit.



(v) A surface cap of fine sandy clay varying in thickness from a few inches up to 5-6 feet.

The distribution of the above set of beds presents several points of interest. Unfortunately, the sections through the beds are exposed only near the tops of the high sea-cliffs and in the equally inaccessible gorges of the streams dissecting the plain. As far as could be ascertained, the fossiliferous stratum extends to a point on the coast about 1½ miles west of the Motunau River. It was traced inland also about ¼ mile up the first stream west of the river. The marine greywacke layer immediately overlying the fossiliferous band has a much wider distribution, and was found, becoming somewhat coarser in texture, to extend to the head of this stream, which, however, has not cut back as far as the rear of the plain. Southward the greywacke type occurs in small local pockets only. A section through the surface-cover visible on a slumped face of the sea-cliffs at a point 1¾ miles west of the Motunau River, showed the limestone type to have completely taken the place of the marine greywacke.

The limestone layer extends over most of the area where sections are exposed south of the Motunau River, but in no case could it be found to reach to the inner edge of the plain. Therefore, though more or less sparsely scattered limestone pebbles are found in the covering beds in other parts of the plain, the beds consisting entirely of them are restricted to the southern area. This distribution suggests an entirely local origin, and the fact, that in no case was this facies found at the rear of the plain, suggests the possibility of its deposition during a definite pause in the uplift.

The present writers are agreed that, while the Motunau River and the large stream in the extreme south of the plain may have supplied the material of the limestone layer, the arrangement of the pebbles and the continuity of the bed across the front of this part of the plain suggest its deposition under marine conditions. In this connection, too, sections in the first stream south of the river are especially interesting, for this stream cannot possibly have deposited any of the material itself, as it does not extend to the rear of the plain.

A possible alternative source of supply of the limestone is a longshore drift of material derived by cliffing of the limestone range of Montserrat only a few miles to the south. The very restricted distribution of the deposit, however, favours a hypothesis of more local origin probably connected with the cutting of the Vulcan Gorge by the Motunau River.

The angular greywacke facies, with only scattered limestone pebbles, forming the upper part of the sequence, is also best developed in the southern area. The supply of this, too, may be connected with rejuvenation of the Motunau River progressing headwards. Thus the distribution of the material across the front of this part of the plain may be regarded as the work of the sea, to which it was brought by the rivers now traversing the plain.

2. *The Middle Area.*

Good sections are exposed intermittently in the north bank of the Motunau River near its mouth, in the sea-cliffs, in the banks of the large stream near the Motunau homestead, and in Boundary Creek. The basal fossiliferous stratum is present at the mouth of the Motunau River, where a characteristic feature of the rock surface on which it rests is the frequent occurrence of bored holes in which shells of the marine mollusc *Anchomasa similis* were found. In the sea-cliffs north of the Motunau homestead, and extending ½ mile up the middle creek, the distinctive fossils of this horizon were again found in situ.

At the Vulcan Gorge also, on the planed surface of the Mt. Brown beds at the extreme inner edge of the platform, fragmentary fossils are found in one small pocket. These latter are, however, not well preserved, and no definite pronouncement as to their recent origin could be made. Associated with the fossiliferous band at the mouth of the Motunau River are fairly large blocks of an impure shelly limestone (apparently derived from a stratum in the underlying basement beds) interspersed with small rounded greywacke boulders.

The marine greywacke type immediately overlying the fossiliferous band is widely distributed through this area—notably at the mouth of the Motunau River, in the cliffs facing the sea between the Motunau homestead and Boundary Creek, in the middle creek to within ½ mile of the inner edge of the plain, and at the Vulcan Gorge.

Above the marine greywacke at the mouth of the Motunau River, and along the sea-cliffs towards Motunau homestead, well stratified sands containing richly fossiliferous bands are present. These bands are characterised by *Chione stutchburyi, Amphibola crenata,* and *Macomona liliana.* This assemblage of fossils in such a restricted area strongly suggests local estuarine conditions of deposition.

The Amuri limestone facies appears again in the sea-cliffs where it overlies the estuarine sandy beds, but it is restricted to the neighbourhood of the Motunau River.

In this Middle Area of the plain the angular greywacke and upper sandy horizons are not well represented, but they were observed at some accessible points in the neighbourhood of Boundary Creek.

3. *The Northern Area.*

This section of the plain is well dissected by several vigorous streams. Four of them, Boundary Creek, Manuka Creek, Black Birch Creek, and Stonyhurst Creek, have cut through the hills in the rear of the plain, but tributaries to these major streams, and some shorter consequent streams, are entirely within the plain itself. Good sections are not numerous in any of the streams, being frequently obscured by bush.

Near the north end of the plain, at the mouth of Stonyhurst Creek the covering beds consist of:—

(i) The typical marine greywacke facies, more than usually sandy in parts, and containing, at or near the base, scattered marine shells succeeded by

(ii) Yellow sandy beds, and

(iii) Greywacke gravels of a more angular nature with Amuri limestone pebbles sparingly throughout.

This is the only locality where the covering beds were found to vary notably in thickness, and to rest on a surface which is not approximately flat. The base on which they lie is concave in the axis of an older syncline affecting the basement beds. This syncline shows the beds of the eastern limb dipping very steeply inland, while those of the western limb are much flatter. Renewal of synclinal folding appears to have warped the cut surface of the basement beds into a trough in which the covering beds are thicker than usual, the upper surface remaining, however, fairly even.

In the sea-cliffs, south of Black Birch Creek, the marine greywacke gravel in a matrix of fine sand forms a bed 20 feet thick, with occasional fragments of bored sandstone at its base. This gravel passes upward into fine sand which is succeeded by more angular greywacke gravel with fragments of Amuri limestone. This last thins out to the south. Southwards along the coast the cliffs increase slightly in height on account of the occurrence of thick beds of yellow sandy clay forming an extra surface accumulation. The level of the cut platform appears remarkably uniform throughout. In places a thick sandy bed is present below the layer of marine greywacke gravels.

A good section through the covering beds is exposed in the north bank of Black Birch Creek at the inner edge of the plain. This shows the usual marine greywacke pebble beds extending to the inner edge of the plain and then disappearing abruptly. As this deposit does not occur on either bank of the stream farther inland, stronger evidence is afforded that its deposition was not the work of the stream. The height here of the extreme inner edge of the plain is 330-350 feet, and the sea must have reached inland to this point as at the Vulcan Gorge.

A good section is also available in a shingle pit on the south bank of Manuka Creek near the point where the Happy Valley road enters the plain. This section shows the presence of the usual well-graded, marine greywacke pebbles, which again are not visible farther upstream than the inner edge of the Motunau Plain, showing that the sea must here, too, have extended across the whole width of the plain.

4. *Motunau Island.*

Unfortunately, on account of weather conditions, the present writers were able to make only a very hasty examination of this area. On the planed edges of the south-easterly dipping basement beds rests a thick cover consisting of:—

(i) Sandy material containing *Macomona liliana* and *Chione stutchburyi* similar to the deposits already described from the north bank of the Motunau River, and embodying, at the base of the series, occasional blocks of bored sandstone, followed by

(ii) Beds in which pebbles of Amuri limestone predominate, and

(iii) Angular greywacke pebbles in a matrix of sand. Sometimes this bed is consolidated (probably by lime) into a hard mass.

(c) The cut platform.

The base on which the covering beds rest was found throughout the area to exhibit a remarkably even profile, and a surface devoid of even minor irregularities except at two points, viz.:—(i) Just south of the Motunau River, and (ii) at the mouth of the Stonyhurst Creek.

Close examination of the cut platform was made. Firstly, to see if the nature of its profile would afford any explanation of certain surface irregularities of the plain; and, secondly, to examine the possibility of its having been cut by agencies other than the sea.

At the extreme south end of the plain there is a notable increase in the height of the surface, but the cut platform as exhibited in the sea-cliffs is almost perfectly horizontal. This shows the increase of height to be due in this case to an extra accumulation of covering material, and it appears most obvious to suggest that it is of the nature of alluvial fan detritus deposited after the uplift of the plain.

Just south of the Motunau River, however, there appears to be some connection between a slight upwarping of the cut platform and the overlying beds, with the formation of the definitely higher frontal portion of the plain exhibited there. This peculiar feature of the plain is discussed in a subsequent section of the paper.

In the major stream valleys it is difficult to obtain continuous upstream sections, but in the sea-cliffs, when allowance is made for variation in the amount of cliff recession from point to point, the cut platform appears to be almost perfectly plane. A more obvious warping of the cut platform at the mouth of Stonyhurst Creek has already been referred to. This warping, however, must have taken place either prior to or during the deposition of the covering beds.

Therefore, whatever local superficial irregularities the plain may present, these appear in most cases to have no connection with irregularities of the cut surface on which the covering beds have been laid. The present writers have been impressed by the general very remarkable uniformity displayed by the cut platform throughout.

The rocks of Motunau Island into which the marine platform has been cut comprise two unconformable formations, an older series of sandy beds similar to those beneath the Motunau Plain, and dipping at about 20° to the S.S.E., and a younger series, the lowest portion of which is a hard shelly limestone containing sandstone fragments. This offers considerable resistance to erosion, and forms the seaward face of the island and a number of reefs extending shoreward.

(d) The inner edge.

Normally a plain of this type is backed by well-defined cliffs, and an attempt has already been made to explain the absence of them from this locality by supposing that the steeper slopes of original cliffs had been reduced to those of the dip slopes of the harder Tertiary rocks which form the hills at the rear of the plain (Jobberns, 1928, p. 546). The complete absence of well-preserved cliffs has led the present writers to consider whether, after all, agencies other than the sea may have cut the platform, as is discussed subsequently in this paper. Reference has also been previously made (Jobberns, loc. cit.) to the marked surface irregularity of the rear portion of the plain.

After re-examination of the whole length of the inner edge of the plain the conclusion has now been reached that, in general, the inequalities may be explained as arising from (i) residual spurs; (ii) alluvial fans; and (iii) dune deposits. It should be noted, however, that such conclusions are based on observation of the position and general appearance of the features, as there are practically no sections to reveal the nature of the material of which they are made. Both writers are agreed that when the plain is viewed as a whole, these inequalities of its inner edge are merely superficial and of minor importance.

(e) The elevated front.

This feature has also been referred to previously (Jobberns, 1928, p. 546), where it was suggested that an apparent longitudinal depression in the middle portion of the plain might be due to a current channel in the original cut platform, or might be a superimposed drainage feature connected with warping during uplift. In reconsidering the whole question, the present writers have given particular attention to the area just south of the Motunau River. Here an elevated flat-topped front portion of the plain is most strikingly developed, but the feature continues as far north as Black Birch Creek, and a possible remnant of it appears again in the extreme north end of the plain, beyond the mouth of Stonyhurst Creek. The following hypotheses as to its origin were considered in the field:—

(1) Primary—i.e., due to a current channel having existed in the original cut platform.

(2) Secondary—(i) A superimposed erosion feature.
(ii) A tectonic feature.

Examination of the section through the raised front portion in the sea-cliffs south of the mouth of the Motunau River revealed the following facts which seem to be best explained by assuming a tectonic origin.

Firstly, the surface of the platform cut in the basement beds slopes locally slightly inland.

Secondly, the covering beds also slope slightly inland parallel to the cut surface.

Thirdly, while the front of the plain is higher than the main middle portion, its surface presents a similar seaward slope (which is in alignment with that of the top of Motunau Island). This definitely gives the impression that the front of the plain has been raised differentially.

If this differential movement was connected with faulting or monoclinal folding there should be some evidence of it in disturbance of the basement rocks of the platform. Therefore the best explanation seems to be that gentle upwarping of the front part of the plain has taken place in a direction parallel to the present coast, and this explanation accords with all the facts noted above. This warping probably occurred at some stage in the uplift of the plain, and subsequently to the establishment of the present system of parallel consequent drainage channels.

There seems to be no evidence for regarding the longitudinal depression as having been occupied at any time by a single stream flowing parallel to the coast.

B. THE MODE OF ORIGIN OF THE PLAIN.

A levelled surface of the type exhibited in the Motunau Plain may conceivably be formed by any of the following agencies:—

(a) By lateral planation by rivers flowing parallel to the existing coast.

(b) By the coalescence of the flood plains of numerous streams flowing at right angles to the existing coast.

(c) By normal marine planation.

One of the present writers (King, 1930, p. 520) has set out certain criteria for the discrimination between coastal plains of marine and those of alluvial origin. These criteria have been considered in relation to the Motunau Plain, and for the purpose of general comparison of types a brief examination was made of the broad raised flood plain of the neighbouring Greta Valley. Therefore the writers have discussed in the field the possibility of the Motunau Plain having had an alluvial origin of either of the above types, viz.:—

(a) By one river parallel to the present coast.

The Greta Valley presents a broad uplifted flood-plain into which the formerly meandering river has become deeply entrenched. It is evident that if all the seaward ranges were removed by marine erosion, so that the present plain became bounded by the resulting shoreline, it would present many features comparable with a normal uplifted plain of marine erosion. Its profile now is biconcave, but a normal seaward sloping profile would be produced by the cutting away of approximately half the present plain. Indeed, the present Greta Valley actually presents a more even surface than do many observed marine platforms. The superficial deposits, however, consist in the main of angular and subangular gravels, ill-sorted, and, for the most part, not well stratified. The plain also has a general down-valley slope so that if it were made to appear level, back tilting through exactly the angle of this slope would be necessary. Its western edge is determined by the dip slopes of the rocks of the locality, in which entirely structural feature it closely resembles the inner edge of the Motunau Plain.

From the general appearance and position of the latter plain, it appears incredible that whole seaward ranges have been cut away. Moreover, the plain is very wide, and even on Motunau Island the surface still slopes seawards, so that if it originated in this manner it must have been at least 6 miles wide. Furthermore, it definitely has not a general longitudinal slope in one direction, being, if anything, highest in the middle. In any case there is not now any river in the locality sufficiently large to cut such a terrace.

(b) By the coalescence of the flood plains of numerous streams at right angles to the coast.

A characteristic feature of the rivers of this part of Canterbury is their anteconsequent nature, in which they resemble the Hurunui River, which flows across the present grain of the country (Speight, 1918, p. 100). The Motunau River and five lesser streams of the locality are of this type, inasmuch as they flow in deep gorges through the hills in the rear of the plain and across the strike of the country.

In general, these hills represent merely seaward dipping outcrops of the harder members of the local Notocene sequence (Jobberns, 1928, p. 543).

It is possible that the peneplanation of the uplifted surface of such a land might be carried on by streams such as these, leaving the harder rocks standing as hills and planing the softer beds in front of them. In such a case the deposits on the planed surface would be entirely alluvial, and the inner edge of the plain would probably present a sinuous outline instead of the present remarkably smooth curve. Furthermore, the sea coast sections show the surface of the cut platform extending as an almost perfectly horizontal line from one stream channel to the next. It is very unlikely, though not impossible, that such remarkable surface uniformity would be displayed by a platform cut by streams in the manner suggested above.

Indeed, if either of the above hypotheses be accepted to account for the cutting of the platform, it becomes necessary to postulate subsequent depression, accompanied by complete removal of any alluvial cover, to enable marine beds and fossils to accumulate on it.

(c) By normal marine agency.

It will now be convenient to correlate the more important of the facts recorded in the first part of this paper, and at the same time to consider in turn the criteria already mentioned (King, 1930, p. 520).

(i) *General appearance, extent, position, and relative proportions of the terrace.*

The position of the plain adjacent to the present coast, its broadly arcuate inner edge, the ratio of its length to its breadth, and its general appearance in relation to the rest of the country suggest immediately to the observer that it has emerged from the sea.

(ii) *Character and distribution of the covering deposits.*

The most strikingly developed and widely distributed of the covering beds is the band of well rounded, evenly graded, well stratified, and sometimes fossiliferous greywacke gravel. This has been recorded from almost all parts of the plain where good sections are available, and it has been shown to be present in three places distributed along the entire length of the inner edge of the plain at a height of 350 feet, where it disappears abruptly.

The pebbles, though usually somewhat flattened, were not of a discoidal form, but both writers regard the deposit as a whole to be typically marine. Moreover, this band usually lies on or near the surface of the basement beds, so that it was most probably deposited in position by the sea, which also cut the platform. With regard to the increasing angularity of the upper members of the covering series in many places, this is only what might be expected to result from elevation, causing rejuvenation of streams and increasing greatly the supply of waste to the sea. If elevation proceeded at any appreciably rapid rate, this material would be left on the platform as evidence merely of the lack of time for its shaping and sorting by the sea. Its texture and its angular nature certainly suggest an alluvial origin, but its distribution just as strongly suggests the work of the sea.

(iii) *The slope of the rear edge of the terrace.*

Except for minor surface inequalities, the inner edge of the platform is remarkably level from end to end through a distance of 12 miles. This must be taken as strong evidence of marine origin, and an indication of a very regular uplift.

(iv) *Presence or absence of cliffing at the rear.*

In this respect the evidence for a marine origin is not strong. Well preserved cliffs are not present. It has been suggested previously that this is a function of the structure of the country (Jobberns, 1928, p. 545). Apart from this, however, ample evidence has been quoted to show that the sea has in the past reached to the inner edge of the terrace. Therefore either steep cliffs were never formed (possibly owing to the breadth of the platform reducing the cutting power of the sea), or such cliffs as were present have since been graded so that they now coincide with the dip slopes of the hills behind the plain.

(v) *Presence of "island" interfluves.*

Such features are not present. The irregularities of surface relief at the front of the plain cannot be regarded as of this nature, and they have been herein attributed to other causes.

(vi) *Presence of marine shells.*

The presence, on an uplifted platform, of marine shells which can be proved to be in position must be regarded as incontrovertible evidence that the platform has emerged from the sea.

It is possible to derive a fossil fauna from older rocks eroded by a river and deposited in the covering beds of a platform. Also it may be possible to have more recent shells deposited on a river cut platform which has been depressed and re-elevated. In this latter case, however, it is extremely improbable that the fossils would be deposited immediately on the cut surface of the platform from which a former alluvial cover would have to be stripped.

In the case of the Motunau Plain, fossiliferous beds are widely distributed, lying immediately on the surface of the cut platform, in which the marine borer *Anchomasa similis* is found actually in the holes which it excavated. This seems almost conclusive proof that the sea not only deposited the covering beds, but also cut the platform.

C. CONCLUSION.

The Motunau Plain is exceptional in that it is the only high-level terrace on the coasts so far examined in detail by either of the present writers where recent marine shells have been found in position. McKay (1886, p. 126; 1890, p. 181) recorded Recent marine shells at Amuri Bluff at a height of 500 feet, but these have not subsequently been found. It seems, therefore, that in this general absence of fossils other criteria must be relied on, and can with reasonable certitude be used for the determination of the mode of origin of the other shore platforms of our coasts.

The foregoing discussion raises the question of what may be regarded as reasonable proof that the sea planed a terrace which has emerged from it, or that a coastal terrace has ever been submerged.

Though the observer viewing a coastal platform as a whole may be convinced that it is of marine origin, only in rare and very fortunate cases can he state a series of points which prove conclusively that the sea actually cut the platform; and it therefore seems unreasonable to the present writers that a full and definite proof should be expected for every platform.

There are, on the coasts of New Zealand, many extensive benches which have practically no remaining surface cover to afford evidence of a former submergence. There are, too, in parts of the country distant from the sea, various types of bench-like level surfaces in the higher districts. With these latter also, definite evidence is so scanty that one can again adopt only the simplest explanation suitable to the local circumstances.

In the case of the Motunau Plain, proof of emergence of the land through a height of 350 feet is obtained from the surface cover and its fossil content; but it may be argued that the surface was planed by other agents of erosion before being submerged to receive this marine fossiliferous cover. Even the occurrence of the shells of *Anchomasa similis* in the holes it bored in the surface of the platform is not absolute proof that the sea cut the platform.

In view of the fact, however, that other theories require such a nice adjustment of successive drownings and uplifts, and appear so forced in their application it seems practically certain that the sea was not only responsible for the arrangement and formation of the covering beds, but also carved the platform on which they rest. In this respect the Motunau Plain offers much stronger evidence of an entirely marine origin than does any other platform examined by either of the present writers.

It is therefore hoped that this paper will provoke discussion which may lead to clearer and more definite ideas of the nature and mode of origin of our coastal terraces.

APPENDIX.

Lists of Fossils from the Covering Beds, Motunau Plain.

In 1927 Mr E. W. Bennett, late of the Canterbury Museum, examined a collection of fossil mollusca from the covering beds of the Motunau Plain submitted to him by one of the authors (Jobberns), and stated that they might all be referred to Recent species. This collection has, unfortunately, been subsequently dispersed, and was not available for re-study. Towards the end of 1929 another collection was made by Dr. D. W. Johnson and the late Mr S. J. H. Sylvester and lodged for examination with Dr. J. Marwick of the N.Z. Geological Survey. Lists from this collection have not been published, but Dr. Marwick has very kindly permitted the present writers to add a supplementary list of his determinations to their own.

Locality 1.—North Bank, Motunau River, one chain from the mouth.

Upper Horizon.

C elotrochus tiaratus (Q. & G.).
Zediloma digna Finlay.
Mucrinops urbanior Finlay.
Lepsithais lacunosa (Brug.).
Mytilus planulatus Lamk.
Aulacomya maoriana (Iredale).
Mactra discors (Gray).
Spisula aequilateralis (Desh.).
Tawera spissa (Q. & G.).

Middle or estuarine Horizon.

Amphibola crenata (Martyn).
Macomona liliana (Iredale).
Chione stutchburyi (Gray).

Lowest Horizon.

Anchomasa similis (Gray).

Locality 2.—Top of Sea Cliffs, ten chains south of the mouth of the Motunau River.

Coelotrochus tiaratus (Q. & G.)
Micrelenchus tenebrosus (A. Adams).
Mucrinops urbanior Finlay.
Dardanula roseola (Iredale).
Stiracolpus symmetricus (Hutton).
Maoricolpus cf. roseus (Q. & G.).
Zegalerus tenuis (Gray).
Sigapatella novae-zelandiae (Lesson).
Buccinulum aff. *littorinoides.*
Buccinulum kaikouraense Powell.
Xymene plebejus (Hutton).
Axymene cf. *turbator* Finlay.
Axymene corticatus (Hutton).
Lepsithäis lacunosa (Brug.).
Zemitrella choava (Reeve).
Zemitrella pseudomarginata (Suter).
Alcithoe sp.
Baryspira depressa (Sow).
Austrodrillia chordata (Suter).
Melatoma buchanani (Hutton).
Guraleus sinclairi (E. A. Smith).
Kerguelenia australis (Q. & G.).
Dentalium sp. indet.
Aulacomya maoriana (Iredale).
Limatula maoria Finlay.
Ostrea sinuata Lamk.
Venericardia purpurata (Desh.).
Mactra ovata (Gray).
Tawera spissa (Q. & G.).
Paphirus largillierti (Phil.).
Notirus reflexus (Gray).
Gari stangeri (Gray).

In addition to some of the above listed species, the following were identified by Dr J. Marwick from the collection made by Dr Johnson and the late Mr Sylvester.

Locality 2.

Notoacmaea daedala (Suter).
Micrelenchus sp.
Conjectura glabella (Murdoch).
Subonoba 2 n. spp.
Estea cf. *zosterophila* (Webster).
Estea cf. *impressa* (Hutton).
Estea cf. *subfusca* (Hutton).
Turbonilla sp.
Odostomia densilirata Suter.
Odostomia n. sp. aff. *huttoni.*
Terebratella inconspicua Sow.
Nucula hartvigiana (Pfr.).
Lissarca cf. *exilis* Suter.
Hochstetteria cf. *meleagrina* Bern.
Cosa filholi (Bern).
Chlamys cf. *celator* Finlay.
Venericardia (Pleuromeris) n. sp.
Verticipronus cf. *mytilus* Hedley.
Condylocardia crassicosta Bern.
Notolepton sanguineum (Hutton).
Lasaea minutissima Iredale.

Comparison of the faunas indicates that Locality 2 is the same as the Upper Horizon at Locality 1. Thus ten chains west of the mouth of the Motunau River the estuarine or *Macomona* facies below the marine cover is not present. The ancient estuary extended eastwards, however, at least as far as Motunau Island (q.v.) and for some distance northward, where the estuarine beds with their characteristic fossils outcrop continuously along the top of the present marine cliffs.

Comparison was made with the present distribution of all the species recorded, but in view of the incompleteness of our knowledge of this department no safe conclusions could be drawn. It seems tolerably certain, however, that the fauna is very close to the existing forms on the littoral at Motunau to-day.

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Two New Molluscs of the Pectinidæ from 600 to 700 Fathoms, Four Hundred Miles West of New Plymouth.

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THE two important additions to our fauna which are described below were collected recently from deep-sea cable by Mr W. Foster, of the cable steamer "Recorder." The locality was about 400 miles west of New Plymouth, and the depth between 600 and 700 fathoms.

Both species belong to the *Pectinidae,* and one of them, the *Palliolum,* represents a genus new to our Recent fauna, although species of the closely allied Mesozoic genus *Camptonectes* are recorded from the Cretaceous of New Zealand. It is, in fact, doubtful if there is any real distinction between the genera *Camptonectes* and *Palliolum.*

The only other molluscs present were a number of juveniles of a thin, fragile, and very variable *Anomia,* which at that stage could not be separated with certainty from the common inshore species *trigonopsis* and *walteri.**

The Anomias occurred on the valves of the *Palliolum.*

Genus PALLIOLUM Monterosato, 1884.

Type (by subsequent designation, Cossmann and Peyrot, 1912): *Pecten testae* Bivona, Recent, Mediterranean.

Palliolum fosterianum n. sp. (Plate 40, Figs. 6 and 7).

Shell of moderate size for the genus, subcircular, convex, very thin, translucent white, having faint "*Camptonectes*" divaricating striations, and minute rather distant hollow granule-like scales, which occur on the concentric lines of growth. These scales are usually worn off in the middle of the valves, but remain intact at the sides, where they appear as several radial series. In the holotype, which is 20 mm. in height, the striations are about 8 per mm., and the concentric growth-lines 3 per 2 mm., at the middle of the shell. Hinge-line straight, ears unequal, produced a little longer anteriorly. Sculpture of anterior ear in right valve consists of six rows of imbricating radial ribs which are crossed by the concentric growth-lines. The posterior ear of the right valve and both ears of the left valve are without radial sculpture except for the growth-lines and "*Camptonectes*" striations. Byssal notch deep and wide, with a broad fasciole, and a ctenolium with four free teeth. Apart from the byssal notch the margins are entire, close fitting, thin, and not bevelled. The beaks are small, sharply pointed, and approximate.

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* Finlay (1926, *Trans. N.Z. Inst.,* vol. 57, p. 447) considers that *trigonopsis* and *walteri* are probably identical.

Interior glassy, polished, muscle-scar indistinct. Ligamentary pit very small and shallow.

Height 20 mm.; width of valves 19.75 mm.; width of hinge-plate 12 mm.; thickness (two valves) 6 mm. (holotype, fig. 6).

Holotype and several paratypes in Auckland Museum.

This new species appears very like the deep-water Atlantic *Chlamys (Palliolum) chaperi* Dautzenberg & Fischer.* The New Zealand species differs from the Atlantic one in being more circular, in having a proportionately longer hinge-plate, and in being without a constriction between the hinge-line and the disc; that is apart from the byssal sinus in the right valve.

Unlike the colourless, translucent *fosterianum* the Mediterranean genotype is brightly coloured, but on shell characters it is very similar to the New Zealand species.

The species is named after Mr W. Foster, of the cable steamer "Recorder," who, by collecting material from cables at every opportunity, has done much to further our knowledge of deep-sea life in Australasian waters.

Another related species is the deep-water *Pecten kermadecensis* E. A. Smith, which was dredged by the "Challenger" at Station 171, north of the Kermadec Islands, in 600 fathoms.†

Genus CHLAMYS Bolten, 1798.

Type (by subsequent designation, Herrmannsen, 1846-47): *Pecten islandicus* (Linnaeus) = *Ostrea islandica* Gmelin in Linnaeus, 1791 = *Pecten islandicus* Muller, 1776.

Chlamys kiwaensis n. sp. (Plate 40, Figs. 1-5).

Shell of medium size, thin, suborbicular, compressed, equivalve, but with ears very unequal. Sculptured with rather distant, rounded, partly scabrous, strong radial ribs with fine radially striated interspaces. Colour of both valves dull-white, but with the radials of the left valve only marked out in brownish-pink. Beaks small, sharply pointed, approximate. Anterior ears large, twice the length of the posterior ones. Right valve with a broad fasciole; ctenolium broad and rather shallow, with four free teeth. Anterior ear of right valve with four scabrous radial ribs, that bordering the hinge-line being widest. Posterior ear of right valve with four evenly spaced and equally developed scabrous radial ribs. In the left valve there are eight anterior and three posterior scabrous radials. The disc is sculptured with 31 simple narrow radials which bear towards the margin sharp imbricating spines. Interspaces from three to five times width of radials, smooth to the eye, but really delicately sculptured with microscopic radial striae crossed by " *Camptonectes* "-like divarications. Ligamental pit small and shallow. Interior of shell dull white, with brownish-pink ribs showing through in right valve.

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* *Chlamys (Palliolum) chaperi* Dautz. & Fischer. Station 584, 38° 31′ N., 26° 49′ 15″ W. in 845 metres. Dautzenbergh, Ph. 1927. Resultats des Campagnes Scientifiques du Prince de Monaco. Mollusques. Provenant des Campagnes Scientifiques du Prince Albert 1er de Monaco dans l'ocean Atlantique et dans Le Golfe de Gascogne.

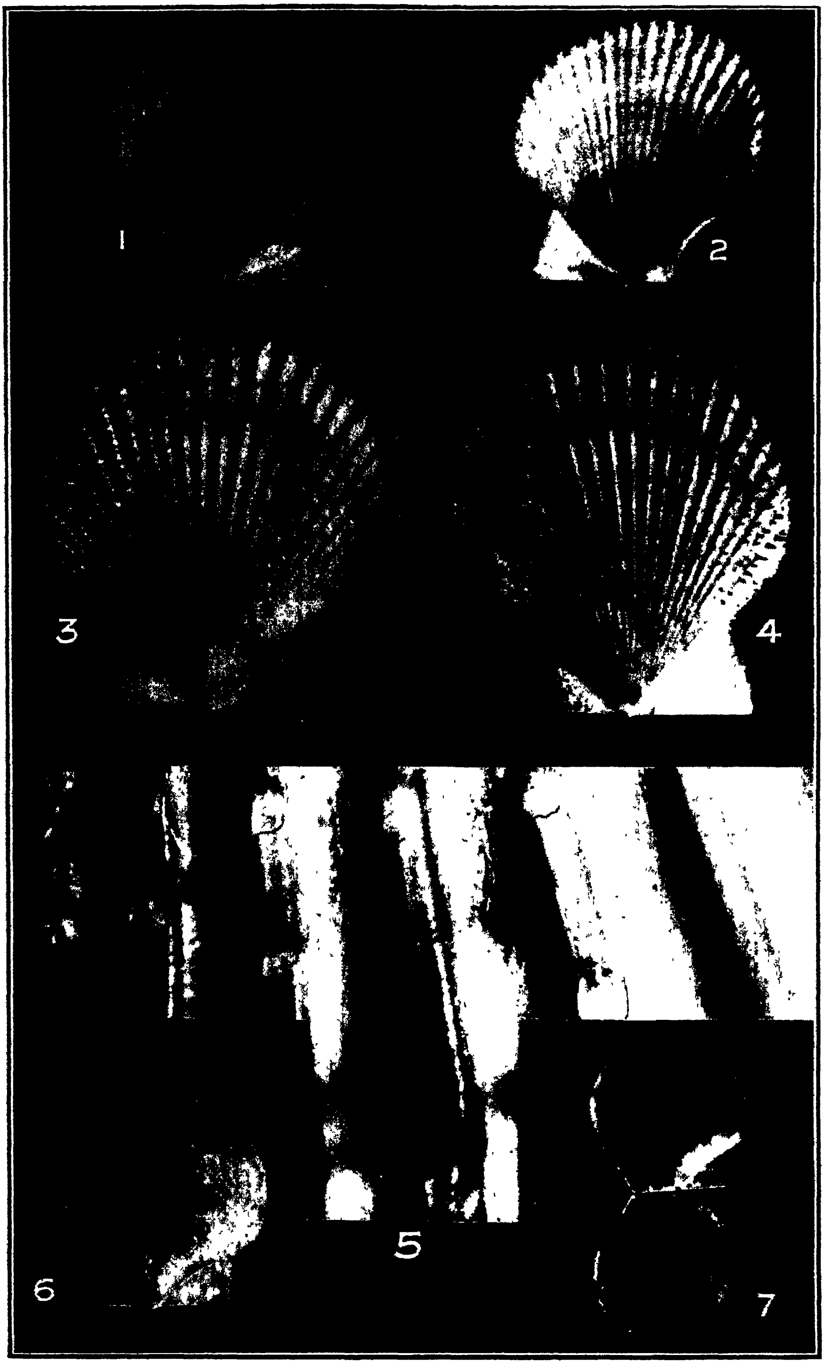
† Challenger Reports, Zoology, vol. 13, 1885, p. 302, pl. 21, figs. 7 and 7a.

Height 33 mm.; width of valves 29.5 mm.; width of hinge-plate 16 mm.; thickness (two valves) 9 mm. (holotype).

Holotype and three paratypes in Auckland Museum (Figs. 3, 4, and 5).

The Tertiary *Chlamys compitum* (Marwick) from Chatton and Wharekuri is very similar to this new species, both having distant rounded scabrous simple radials without intermediate radials.

The name of the species is based upon the Maori for the ocean—Te moana nui a kiwa—the great ocean of Kiwa.



FIGS. 1 & 2.—*Chlamys kiwaensis* n. sp. (paratype). × $\frac{3}{4}$
FIGS. 3 & 4.—*Chlamys kiwaensis* n. sp. (holotype). × $\frac{3}{4}$
FIG. 5.—*Chlamys kiwaensis* n. sp. (detail of sculpture; left valve of holotype) × 16.

An Iodine Survey of New Zealand Live-stock.

Part I.

SHEEP AND LAMB THYROIDS FROM OTAGO AND SOUTHLAND.

By ETHELWYN MASON.

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THE existence of endemic goitre in New Zealand has long been recognised, and a great deal of work has been done in tracing its geographical distribution. Investigations of this nature in other countries, notably Switzerland and the United States of America, have justified the conclusion that one of the primary causes of simple goitre is a deficiency of iodine, hence the work carried out in this country, where there are a number of areas very low in iodine, would be expected to throw considerable light on the problem.

In a general survey of New Zealand, C. E. Hercus, W. N. Benson, and C. L. Carter (1925) examined a large number of school children for thyroid enlargement, and made iodine analyses of soils and water samples collected throughout the country as representatively as possible. They concluded that, generally, the incidence of the disease is inversely proportional to the amount of iodine in the soil, and considered that the investigation fully sustained the hypothesis that goitre is caused by a deficiency of iodine.

In a more detailed investigation of some of the North Island districts the work was continued by R. A. Shore and R. L. Andrew. They also found that, with the exception of certain anomalies, a general relation existed between the incidence of goitre and low soil iodine.

The occurrence of goitre in wild and domestic animals, with an occasional outbreak of " cretinism " among lambs from certain districts, has shown the need for an investigation into the problem from an agricultural viewpoint. As plant iodine is dependent not on the total iodine in the soil, but on the " available " iodine, it is reasonable to suppose that the nature and type of soil would exert a definite influence on the iodine content of pasture, hence on the iodine intake of herbivorous animals. As the most important factor affecting the iodine of the thyroid gland is the iodine intake (Orr and Leitch), analyses of thyroid glands would be expected to reveal a deficiency of intake. Accordingly B. W. Simpson (1930) during a visit to New Zealand from the Rowett Research Institute made a brief survey of the iodine content of sheep and lamb thyroids collected throughout New Zealand. She found an enormous variation in the percentage of iodine in the glands, and showed that a deficiency was nearly always associated with enlarged glands. She concluded that the iodine content of thyroids of lambs born and bred on definite areas gave a fair indication of the amount of iodine available on these areas, and that systematic advisory work on iodine feeding could be based on such analytical data, but that, however, more data and more widespread investigations were required.

Similar work in Australia has shown a relatively small variation in the iodine content of thyroids from sheep, with no indications of thyroid enlargement. The authors conclude that so far as they have investigated there is no trace of an iodine deficiency in Australia (Dawbarn and Farr, 1932).

This paper embodies results from part of a more extended survey of New Zealand. The districts of Otago and Southland have been studied in considerable detail. No definite system of classification other than that of geographical distribution has as yet been adopted, for it is considered that as data accumulate, some natural basis of systematic classification such as geological formation may present itself. The effects of geomorphology, climate, soil, and manurial treatment are considered, and their possible influences on the available iodine in soil.

Sampling: All samples from Otago and Southland were obtained through the District Superintendent at Dunedin by the meat inspectors at the various freezing works throughout the country. Information as to the history of sheep and type of country where they were raised was obtained by the local stock inspectors and veterinarians. The glands were wrapped in greaseproof paper (sprinkled with a little 10 per cent. formalin solution during the hottest part of the summer), packed tightly in small tins, and forwarded to the laboratory. There they were dissected free from fat and tissue, dried to constant weight in a water-oven, treated with a 10 per cent. solution of caustic potash, made up to a given volume, and stored for analysis.

Owing to the difficulty in obtaining whole glands from "butcher" killed sheep, samples were sometimes more or less mutilated, hence a short preliminary investigation was made to determine the distribution of iodine throughout the gland, and the possible effect of mutilation on the percentage of iodine.

Eleven glands, both normal and slightly enlarged, were selected at random from sheep, and carefully dissected free from fat and tissue. These were then cut in pieces both transversely and horizontally, and the pieces analysed separately. The isthmus generally contained a slightly smaller percentage of iodine, whereas in the remainder of the gland iodine was very evenly distributed. The results justified the assumption that a loss of a small portion of a gland would not significantly affect the whole percentage of iodine. Badly mutilated glands were discarded.

TABLE I.

Sample.	Fresh Wgt. Grams.	% Iodine.	Total Iodine Grams.	Remarks.
1	1.727	0.119	0.0021	Right lobe.
	0.166	0.091	0.00015	Isthmus.
	1.610	0.123	0.0020	Left lobe.
	3.503	0.119	0.0042	Whole gland.
2	2.196	0.163	0.0036	Right lobe.
	0.148	0.118	0.00016	Isthmus.
	2.218	0.168	0.0037	Left lobe.
	4.562	0.164	0.0075	Whole gland.
3	2.284	0.144	0.0033	Right lobe.
	2.508	0.146	0.0037	Left lobe.
	4.792	0.145	0.0069	Whole gland.
4	3.536	0.162	0.0058	Right lobe.
	0.065	0.108	0.0007	Isthmus.
	3.776	0.175	0.0065	Left lobe.
	7.377	0.167	0.0133	Whole gland.
5	2.242	0.156	0.0035	Right lobe.
	0.337	0.156	0.00053	Isthmus.
	2.683	0.153	0.0041	Left lobe.
	5.262	0.155	0.0082	Whole gland.
6	4.815	0.054	0.0026	Right lobe.
	0.104	0.057	0.0006	Isthmus.
	4.012	0.058	0.0023	Left lobe.
	8.931	0.056	0.0050	Whole gland.
7	3.069	0.101	0.0031	Right lobe.
	0.367	0.083	0.0003	Isthmus.
	3.071	0.101	0.0031	Left lobe.
	6.507	0.100	0.0065	Whole gland.
8	1.591	0.111	0.0018	Right lobe, long. section.
	1.620	0.132	0.0022	
	0.190	0.089	0.0002	Isthmus.
	1.866	0.123	0.0023	Left lobe, long. section.
	1.621	0.139	0.0023	
	6.888	0.125	0.0087	Whole gland.

Sample.	Fresh Wgt. Grams.	% Iodine.	Total Iodine Grams.	Remarks.
9	2.153	0.092	0.0020	Right lobe, long. section.
	1.651	0.098	0.0016	
	0.107	0.073	0.00008	Isthmus.
	2.181	0.095	0.0021	Left lobe, long. section.
	1.276	0.076	0.0010	
	7.368	0.092	0.0067	Whole gland.
10	0.860	0.126	0.0011	Right lobe, transverse section.
	0.994	0.124	0.0012	
	0.149	0.129	0.0002	Isthmus.
	1.289	0.132	0.0017	Left lobe, transverse section.
	1.183	0.130	0.0015	
	4.474	0.129	0.0058	Whole gland.
11	0.547	0.068	0.0004	Right lobe, transverse section.
	0.721	0.083	0.0006	
	0.048	0.034	0.00002	Isthmus.
	0.551	0.080	0.0004	Left lobe, transverse section.
	1.181	0.083	0.0010	
	3.048	0.079	0.0024	Whole gland.

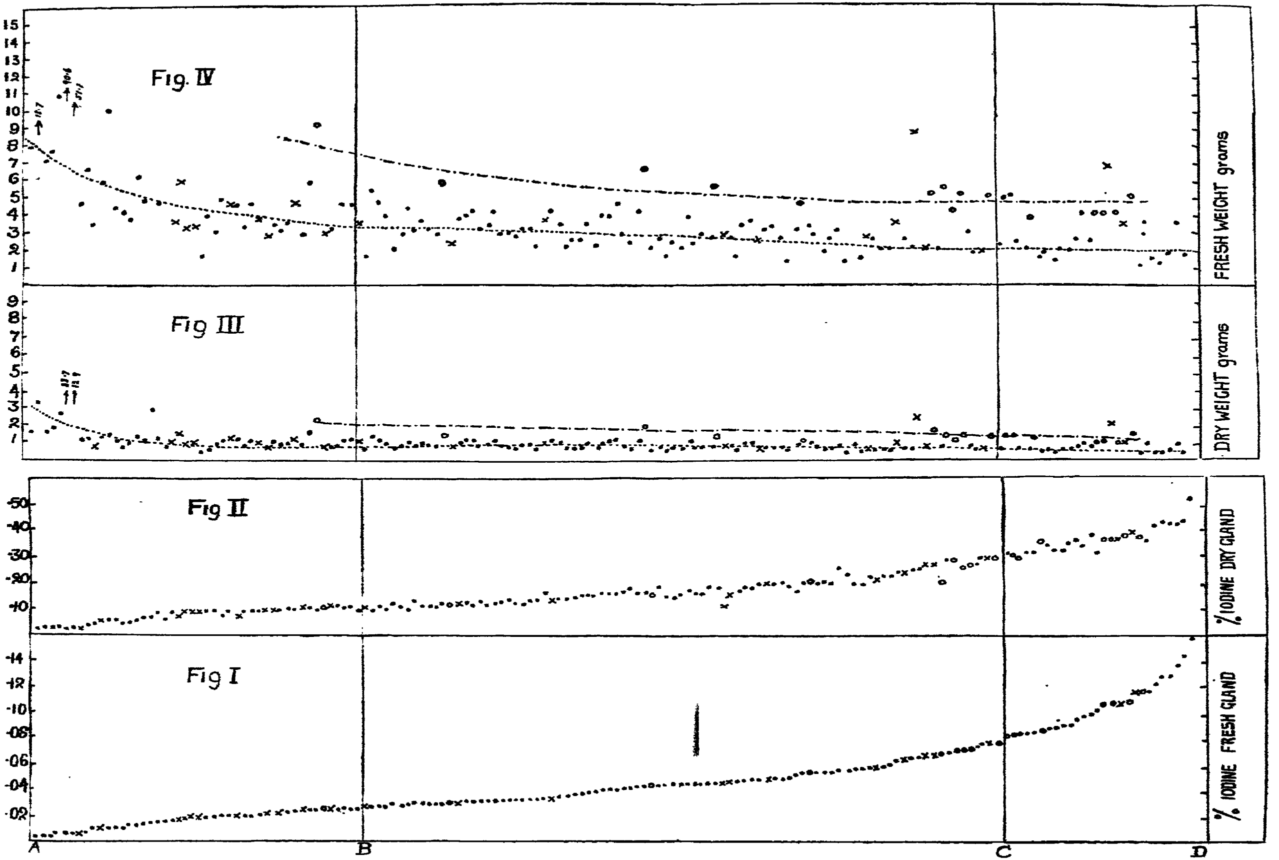
A composite sample was taken from each flock investigated, in order to minimise as far as possible individual variation. Wherever individual glands showed a definite abnormality as regards size or texture they were treated separately.

Analyses of glands were made, with slight modifications, by the method of von Fellenberg as described by Leitch and Henderson (1926). The percentage of iodine is calculated both on the fresh and dry weight basis. The weights of glands given in the tables represent in each case the average weight of one gland from the given samples.

In Fig. I are the samples listed in the following tables, and arranged in order of increasing percentage of iodine, calculated on the fresh gland basis. The same order of the samples is kept throughout Figs. I-IV, so that the variation of other properties with the percentage of iodine on the fresh weight can be illustrated diagramatically.

The arrows in Figs. III and IV indicate much enlarged glands, the weights of which fall outside the diagram. Throughout this paper, unless stated to the contrary, weight and percentage of iodine refer to that of the fresh glands.

Moisture: The samples examined have an average moisture content of about 74 per cent. The actual variation of moisture was from 61.2 per cent. to 87.8 per cent., and the weights of glands examined ranged from 1 to 90 grams, of which one gland weighing 90.6 grams had a moisture content of 73.8 per cent., and one weighing 1.04 grams had 73.2 per cent. moisture.



The dots represent samples of thyroid glands from lambs, the circles samples from grown sheep, and the crosses samples from lambs which have had access to iodised licks. These are arranged in order of increasing iodine content, irrespective of other properties, the same order being kept in Figs. II-IV. Between A and B fall all samples deficient in iodine (below 0.03%), and between C and D samples which are relatively high in iodine (above 0.08%).

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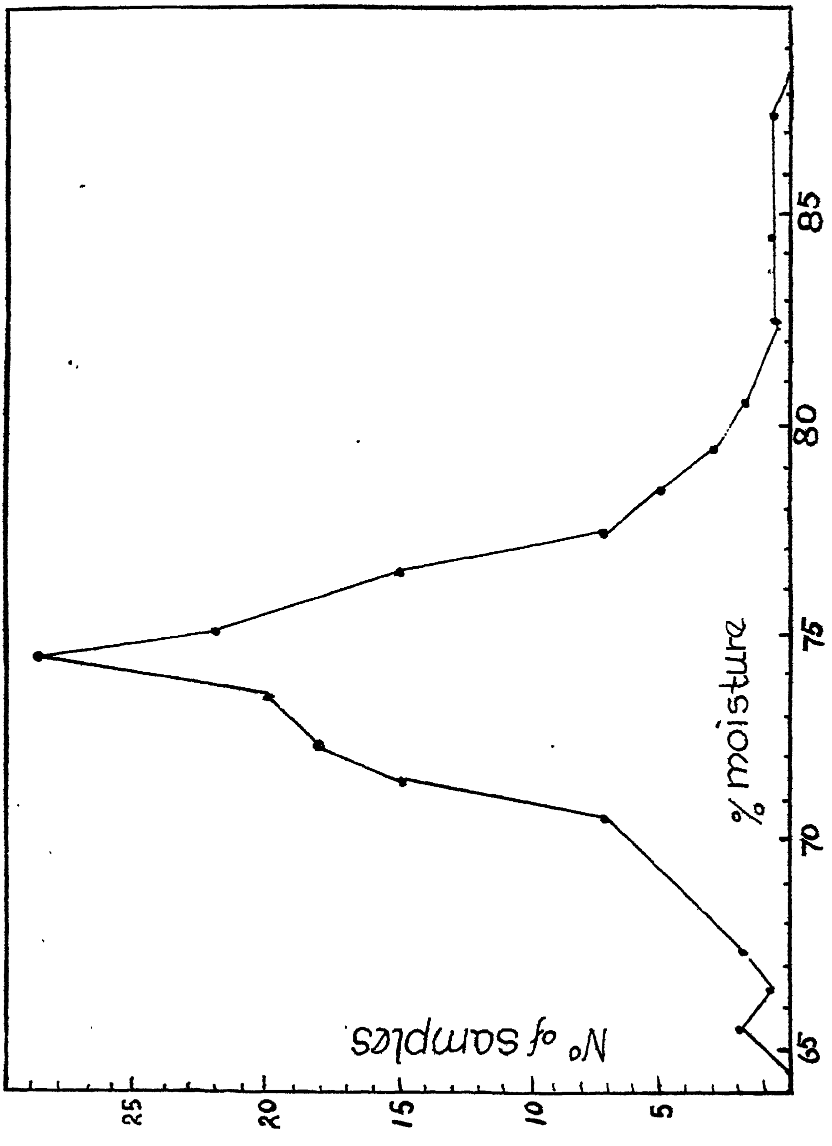

FIG. V.

The distribution curve for the percentage moisture in the glands is practically symmetrical. A general increase in moisture due to the pathological condition of the samples may have occurred, causing the curve to shift as a whole towards the right. This can only be proved by comparison with a similar curve for glands from a district where there are no goitrous tendencies. At present, however, the available data are insufficient for such a comparison.

The Influence of Sex: Samples of glands from ewes and wethers were obtained from 30 different districts. The variation appeared to be due to chance, as the number of glands in each sample was too small to be representative. Dawbarn and Farr for similar reasons are not able to form any definite conclusions regarding the influence of sex other than that the differences were not marked. Variations observed, however, were comparatively small, and would therefore be entirely obscured by abnormalities due to an iodine deficiency.

The Influence of Age: In all the samples examined, glands from sheep are appreciably heavier than those from lambs with the same percentage iodine, hence are not strictly comparable, as they would thus tend to raise the average weight for a given percentage of iodine. This is true for both normal and deficient glands (see Figs. III and IV). The number of glands examined from sheep, however, was relatively small.

The Variation of Weight with the Iodine Content (Figs. III and IV) : The line drawn through B represents the critical percentage of iodine (0.03 per cent.), so that the glands between A and B are deficient in iodine. The increase in weight with the fall in the percentage of iodine is negligible until this value is reached, where the increase takes place much more rapidly.

The two anomalous glands weighing 8.77 and 6.99 grams respectively can be explained on the assumption that the iodine available to these animals as licks has had the effect of increasing the quantity of iodine in the gland without producing a proportional decrease in size. With these two exceptions, of 100 specimens from uniodised lambs containing 0.03 per cent. of iodine and over, only three weighed as much as 4.5 grams, the greater number weighing between 2 and 4 grams.

Of 44 similar samples containing less than 0.03 per cent. iodine only one weighed as little as 2 grams, the greater number ranging between 3 and 6 grams. Ten weighed over 6 grams. Of these, five were typical goitres, one weighing 90.6 grams.

Glands from sheep show the same general variations as those from lambs.

Iodine Feeding: Among glands analysed, 24 samples were from lambs and sheep which had had access to iodised licks. These glands ranged in weight from 2 to 50 grams, with an iodine content of 0.138 per cent. to 0.006 per cent. With the exception of the two anomalies mentioned above the weights of the glands fall approximately into line with those from animals which have not had access to iodine. This may be caused either by the failure to take the lick or by insufficient iodine in lick. This latter may be due to the incorporation of insufficient iodine when mixing, to the loss of iodine through decomposition of the iodide and subsequent volatilisation, or to the leaching action of the rain. It is, however, impossible to base definite conclusions on these figures, as information regarding the amount of iodine ingested cannot be obtained.

An interesting case occurred at Ruakura (in the North Island) in which a gland weighing 350 grams containing 0.006 per cent. of iodine was obtained from a young bull. The brother of this bull, which also had an enlarged gland, was dosed with potassium iodide. Two months later his gland was obtained and analysed. It weighed 202 grams, and contained 0.057 per cent. of iodine.

Work carried out in Australia by Dawbarn and Farr on the supplementary feeding of iodine to sheep shows that the iodine content of glands from sheep which had had access to iodised licks was only slightly greater than that of glands from sheep with no licks, and that there was no correlation between the proportion of iodine in licks and the increase in the proportion of iodine in the thyroid gland. This is probably due, however, to the exceptionally high iodine content of the glands in the normal state.

Relationship Between the Nature of the Soil and its Iodine Content: In their paper entitled " Endemic Goitre in New Zealand," published 1925, Hercus, Benson, and Carter discuss in some detail the quantities of iodine occurring in various types of soils and the variation with soil origin. In a general summary they conclude that soils with the least iodine are of a sandy nature, with little clay or iron in the ferric state. They are usually pale in colour unless darkened by the presence of ferrous minerals, ironsand, or carbonaceous matter. Soils of the last type are not invariably low in iodine, as the plant-remains in them may contain a good deal of this element. The soils which contain most iodine are in general the fertile brown or red loamy soils.

They find that iodine is relatively abundant in soils derived from igneous rocks, most noteworthy in basic volcanic rocks (basalts and andesites) and in siliceous plutonic rocks (granite). It is not very marked in basic plutonic rocks, and there are very small amounts in siliceous volcanic rocks. It occurs in moderate amounts in those sedimentary rocks (greywackes), in which material was derived from igneous rocks with but little chemical alteration, but is greatly diminished during the metamorphic processes by which the greywackes are recrystallised to form mica schists.

In marine sandstones and greenstones the quantities are small, and only minute amounts occur in grey clays. In the gravel of rivers, etc., iodine is generally deficient, though it may be accumulated in plant remains.

Usually the deep weathering of rock allows a thorough leaching of its debris, producing residual clay which may contain but little iodine. On the other hand, it may be accumulated in clay colloids, if such are present, and in humus, the remains of organisms, and thus becomes fairly abundant in the soil. They therefore conclude that it is not possible to make a definite correlation between the amount of iodine in the soil and its geological origin.

As plant iodine is dependent not on the total iodine in the soil, but on the available iodine, it might be expected to vary with the nature of the soil. For instance, clay and peat, though themselves rich in iodine, give up no iodine to the water in which they are suspended, whereas water rapidly dissolves iodine from shell, grit, and sand. Von Fellenberg *(Iodine in Nutrition,* Orr and Leitch) has shown that iodine is more readily absorbed by plants from an acid soil than from an alkaline.

For the purposes of discussion the results have been listed in order as the farms occur up the river valleys and other naturally bounded areas. Fig. VI, which is a geological sketch map of Southland and Otago, also gives the approximate positions of the farms sampled. Soil descriptions are based on data collected by field officers, and not on laboratory analyses.

TABLE II.

Waiau River.

No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
115A	16/5/32	5.475	1.319	.029	.120	75.9	6	Te Tua
115B	16/5/32	3.603	.893	.050	.201	75.2	8	„
99	25/5/32	18.721	3.201	.003	.018	82.9	2	Clifden
99B	25/5/32	4.744	1.069	.008	.035	77.6	2	„
99C	25/5/32	2.032	.471	.044	.191	76.8	2	„
99D	25/5/32	7.138	1.570	.004	.019	78.0	6	„
122A	26/5/32	2.520	.652	.039	.150	74.1	7	Fairfax
122B	26/5/32	2.313	.376	.043	.174	75.1	8	„
96	4/5/32	1.650	.391	.019	.081	76.3	10	Mt. Linton, Nightcaps

Aparima River.

108A	19/3/32	2.559	.728	.045	.157	71.5	6	Otahuti
108B	19/3/32	1.358	.404	.055	.175	70.2	7	„
109	19/3/32	3.514	.868	.024	.098	75.3	9	Drummond
114A	16/5/32	2.510	.640	.039	.153	74.5	7	Aparima
114B	16/5/32	3.198	.798	.035	.138	75.0	9	„

These farms up the Waiau River are on light soils of an open nature, such as sandstones, which, combined with a comparatively high rainfall—40 to 50 inches—would undoubtedly be subjected to a fairly thorough leaching action, hence low in soluble iodine. The

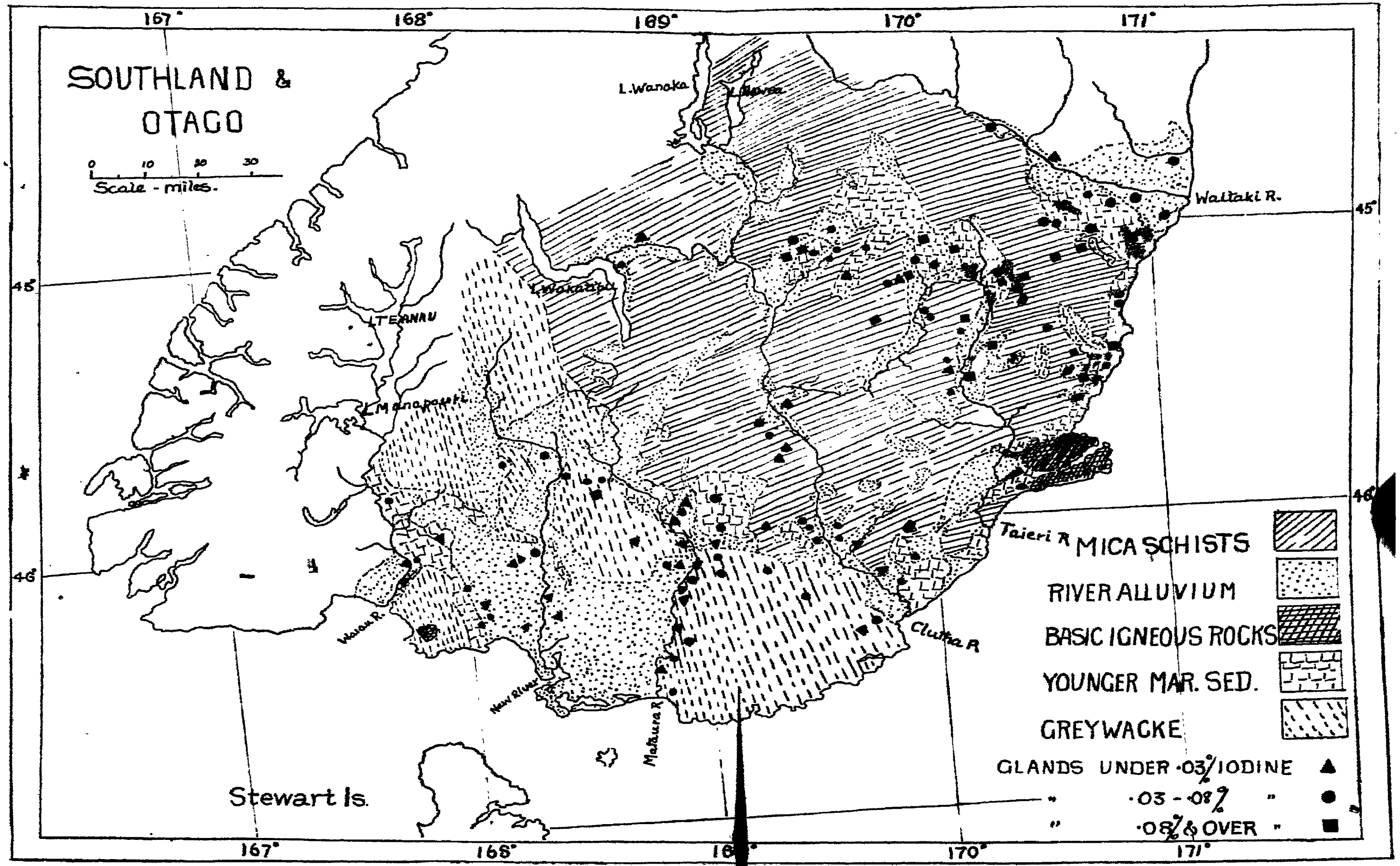

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FIG VI

99 series are from a flock with undoubted goitrous tendencies, and are a particularly good illustration of the direct relationship of increase in weight of gland with decrease in percentage of iodine. In this series also the percentages of moisture increase directly with the weight. Superphosphate is used as a topdressing on this farm. The other samples in the table are from farms which have been dressed with lime and superphosphate.

In the Aparima district there are samples from three farms only. These farms are all on a heavier type of soil, clay and loam, and although they have approximately the same rainfall as the Waiau River, they do not suffer such a drastic leaching action. Lime and superphosphate are used for topdressing. The glands are not deficient in iodine, and, as far as can be told from the number of samples, show no tendency towards enlargement.

TABLE III.

NEW RIVER.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
67A	27/5/32	4.571	1.224	.027	.099	73.2	12	Balfour
67B	27/5/32	3.302	.878	.033	.125	73.4	10	"
106A	1/3/32	2.991	.773	.020	.077	74.2	10	Five Rivers
106B	1/3/32	1.724	.488	.045	.160	71.7	5	"
97A	4/5/32	2.088	.546	.092	.351	73.9	7	Mossburn
97B	4/5/32	1.596	.417	.060	.228	73.9	10	"
111A	20/4/32	6.233	1.256	.014	.070	79.8	6	Oporo
111B	20/4/32	3.932	.896	.030	.132	77.2	7	"
*113A	20/4/32	2.901	.651	.026	.114	77.6	8	Lochiel
*113B	20/4/32	2.674	.662	.022	.090	75.2	9	"
*89A	8/4/32	4.663	1.074	.025	.108	76.9	6	Winton
*89B	8/4/32	3.552	.822	.022	.094	76.8	6	"
98A	9/5/32	3.271	.766	.020	.087	76.6	12	Central Bush
98B	9/5/32	5.787	1.233	.011	.054	78.7	8	"
*112A	20/4/32	3.324	.790	.019	.079	76.2	8	South Hillend
*112B	20/4/32	3.353	.712	.011	.052	78.8	6	"
100A	25/5/32	2.937	.744	.025	.100	74.7	10	Konana
100B	25/5/32	1.783	.476	.049	.185	73.3	6	"

* Access to iodised licks.

The land in this district is mainly flat, with some river-flat, composed of loams and clays derived from river alluvium. It is subjected to a fairly heavy rainfall—30 to 50 inches. Topdressing is mainly superphosphate and lime. It appears from the analyses of glands that iodine is not available in sufficient quantities, though there is no marked tendency to thyroid enlargement. Nos. 113, 112, and 89 are exceptional, as iodine was available to these lambs without having the effect of increasing the percentage of iodine in the thyroid. It is quite possible, however, that these lambs were slaughtered before they had learned to take a lick.

TABLE IV.

Mataura River.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
110A	19/3/32	2.245	.536	.041	.171	76.1	6	Fortrose
110B	19/3/32	4.538	1.100	.042	.177	75.8	5	"
57	12/5/32	7.938	1.573	.003	.013	80.2	10	Mataura Is.
*54	9/5/32	2.706	.725	.060	.223	73.2	4	Glenham
66A	21/5/32	3.917	1.044	.041	.152	73.3	4	"
66B	21/5/32	3.692	.935	.031	.122	74.7	8	"
47A	19/4/32	4.774	1.064	.016	.073	77.7	0	Wyndham
47B	19/4/32	5.976	1.281	.012	.054	78.6	2	"
*50A	22/4/32	3.357	.914	.028	.104	72.8	4	"
*50B	22/4/32	4.480	1.252	.020	.070	72.0	4	"
*93A	23/4/32	3.454	.837	.018	.074	75.8	6	"
*93B	23/4/32	3.212	.804	.019	.075	75.0	7	"
*61A	20/5/32	2.977	.786	.056	.213	73.6	6	Mataura
*61B	20/5/32	3.002	.867	.076	.262	71.1	10	"
60A	16/5/32	3.393	.929	.050	.182	72.6	14	Waimumu
60B	16/5/32	4.622	1.158	.027	.107	75.0	8	"
*65A	21/5/32	3.156	.755	.023	.098	76.1	8	"
*65B	21/5/32	2.800	.703	.026	.104	74.9	6	"
69A	30/5/32	4.158	1.044	.033	.131	75.0	7	Otukarama
69B	30/5/32	2.898	.705	.031	.127	75.7	2	"
70	30/5/32	5.902	1.500	.025	.099	74.6	9	Willowbank
*71A	30/5/32	5.922	1.385	.018	.079	76.6	6	Gore
*71B	30/5/32	2.265	.561	.032	.127	75.2	4	"
52A	22/4/32	3.412	.838	.022	.090	75.4	6	"
52B	22/4/32	4.229	1.014	.033	.136	76.0	2	"
49	19/4/32	4.841	1.083	.020	.088	77.6	6	Mandeville
56	12/5/32	3.722	.868	.013	.055	76.7	4	Otama
64A	21/5/32	3.206	.766	.050	.209	76.1	6	Riversdale
64B	21/5/32	2.841	.697	.034	.138	75.5	8	"
59	12/5/32	7.763	1.706	.006	.028	78.0	4	Otamita
63A	21/5/32	2.510	.668	.086	.322	73.4	8	Balfour
63B	21/5/32	2.197	.597	.087	.322	72.8	12	"
53A	6/5/32	2.064	.527	.038	.147	74.5	6	"
53B	6/5/32	2.878	.713	.034	.135	75.2	8	"
53C	6/5/32	2.180	.542	.045	.182	75.1	3	"
51A	22/4/32	1.908	.527	.057	.205	72.4	4	"
51B	22/4/32	2.184	.601	.063	.229	72.5	2	"

* Access to iodised licks.

With the exceptions of 51, 53, and 63 (Balfour) the samples are from farms with soils ranging from light sandy loams to medium clay loams, which have mostly been topdressed with lime and superphosphate, but 59, 60, 61, 64, 69 have had in addition some guano. With the exception of 59, these samples have all a higher average percentage of iodine, which may in some measure be due to the extra iodine put into the soil by the guano. The samples from Balfour have all a higher iodine content, but they are also from farms where the soil is of a heavier type.

The country as a whole is rolling to hilly; 47 is flat, 52 and 57 are on river flats. The rainfall for this district ranges from 25 to 40 inches.

TABLE V.

LAKE WAKATIPU.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
107A	1/3/32	1.709	.493	.208	.096	71.1	6	Crown Tce.
107B	1/3/32	4.666	1.264	.029	.109	72.8	6	Arrowtown
87	15/3/32	5.644	1.461	.032	.123	74.1	12	Queenstown

The samples are from high rocky country, typical mica schist. This is apparently a border-line district, where a change in conditions such as, for instance, a particularly wet season, might cause an outbreak of goitre. The glands are all from sheep. The number of samples is, however, too small to justify definite conclusions.

TABLE VI.

CLUTHA RIVER.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
73A	30/1/32	2.160	.447	.037	.177	79.3	14	Glenomaru
73B	30/1/32	2.940	.598	.017	.082	79.7	13	”
*74	30/1/32	51.104	12.911	.006	.024	74.7	2	Sterling
84	6/4/32	4.378	.996	.031	.137	77.2	20	Romahapa
72	13/1/32	2.821	.726	.030	.107	74.2	25	Clinton
92	23/4/32	3.665	.958	.037	.140	73.8	22	Wangaloa
†*83	5/2/32	8.770	2.247	.069	.268	74.4	12	Milton
*79	5/5/32	4.263	1.076	.037	.145	74.6	18	Greenfield, Clutha Valley
80	9/5/32	3.393	.892	.037	.142	73.7	24	Tuapeka
81A	9/3/32	2.772	.710	.047	.184	74.4	27	Awamungu
81B	9/5/32	15.342	2.930	.016	.082	80.9	2	Clutha Valley
55A	9/5/32	2.294	.556	.051	.209	75.8	8	Waipahi
55B	9/5/32	2.109	.548	.065	.249	74.0	8	”
82	30/5/32	3.164	.778	.035	.143	75.4	12	Clydevale
58A	12/5/32	3.007	.816	.033	.123	72.8	16	Kaiwera
58B	12/5/32	2.012	.530	.030	.112	73.6	4	”
76	19/4/32	3.132	.786	.058	.231	74.9	23	Clydevale
48	19/4/32	3.222	.820	.055	.217	74.6	6	Maitland
77	21/4/32	4.444	1.092	.012	.048	75.4	40	Clydevale
62A	20/5/32	2.682	.722	.049	.185	73.1	8	Waikaka
62B	20/5/32	3.905	1.044	.045	.167	73.3	6	”
75	15/4/32	4.116	.650	.013	.041	84.2	33	Edievale
78	23/4/32	4.542	1.071	.020	.085	76.4	18	”
*91	19/4/32	3.573	.985	.066	.241	72.4	22	Miller's Flat
90	13/4/32	3.880	.474	.020	.082	87.8	23	Teviot

* Access to iodised licks. † Full-grown sheep.

All the glands from this district, which come from farms where the soil is a heavy clay or loam, have a percentage of iodine just above the critical value, with the exception of 77 (Clydevale). Although the percentage of iodine in these glands is low, they show no signs of enlargement. Most of the topdressing is done with superphosphate and lime; 82, 84, and 89 have used guano as well.

Numbers 73, 74, 75, 79, and 90 are from farms where the soil is light and sandy. With the exception of 79 and 91, where iodised licks have been used, the percentage of iodine in these glands is well below the critical value. Number 74 has also had an iodised lick, but this sample consists of one gland only, which is a typical goitre. The rainfall in the Clutha basin is 20 to 30 inches.

TABLE VII.

Upper Taieri and Maniototo Plains.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
*5	17/2/32	1.997	.556	.081	.292	72.2	22	Middlemarch
86	29/2/32	3.316	.992	.056	.201	72.2	19	Sutton
1	15/1/32	4.685	1.205	.016	.062	74.3	54	Middlemarch
21	21/4/32	3.063	.819	.031	.117	73.3	22	Ngapara
4	12/2/32	1.805	.514	.160	.562	71.5	20	Dunback
3	12/2/32	3.677	1.068	.124	.427	70.9	22	Kokonga
†103	15/2/32	9.299	2.333	.026	.105	74.9	12	,,
*18	15/4/32	3.589	1.066	.117	.395	70.3	20	,,
†15A	14/4/32	4.116	1.176	.073	.256	71.4	22	,,
15B	14/4/32	1.640	.465	.130	.460	71.6	20	,,
6	25/2/32	1.428	.413	.131	.454	71.1	23	Ranfurly
†7	26/2/32	4.999	1.419	.085	.300	71.6	20	,,
†33	18/5/32	5.034	1.631	.118	.365	67.6	12	,,
20A	20/4/32	2.552	.702	.052	.187	72.5	19	,,
20B	23/4/32	1.276	.412	.118	.356	67.7	18	,,
†20C	23/4/32	5.148	1.476	.085	.297	71.3	20	,,
17	15/4/32	2.407	.642	.046	.173	73.3	16	,,
38	23/5/32	3.195	.740	.026	.111	76.8	12	,,
16	15/4/32	3.813	1.030	.033	.122	73.0	16	Waipiata
†27A	13/5/32	3.945	1.155	.108	.369	70.7	22	Wedderburn
27B	13/5/32	1.870	.524	.091	.323	72.0	20	,,
†9	29/2/32	5.161	1.775	.070	.204	65.6	16	Waipiata
†30	13/5/32	4.571	1.142	.055	.218	75.0	18	,,
14	13/4/32	3.766	1.112	.146	.494	70.6	20	,,
9A	29/2/32	1.710	.478	.090	.338	72.0	14	,,
*†26	6/5/32	5.063	1.453	.081	.284	71.2	18	Hyde
101	26/5/32	2.596	.673	.060	.233	74.1	12	Paerau

* Access to iodised licks. † Full-grown sheep.

The soils in this district are mainly alluvial, silt and loam with underlying subsoil of gravel and clay. There are some schist outcrops. This is a district with a very low rainfall (15-25 inches) and a very high rate of evaporation (32 inches). In summer, conditions usually approximate to those of drought. Dawbarn and Farr found that glands collected from sheep under drought conditions contained approximately double the percentage of iodine found in glands from the same localities during a good season. They suggest that this is due to a decreased demand for thyroid hormone owing to the low nutritive level of the sheep and the associated lowering of their basal metabolism.

The increased iodine content of glands from the Maniototo district as compared with those from Southland may be due to reasons such as these, but more probably to the fact that in the soils comparatively large amounts of soluble matter (including soluble iodine salts) are deposited as the ground-water is evaporated from the surface or transpired by plants. Throughout the Maniototo Plains occur small basin-like depressions in which crystalline salt deposits are exuded from the ground. These contain as much as 9000 γ iodine per kgm.,* and are readily eaten by the sheep.

These soils are in direct contrast to those of Southland, where the heavier and well-distributed rainfall promotes a constant leaching, and where saline accumulations are not known to occur.

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* $\gamma = 10^{-6}$ gm.

TABLE VIII.

MANUHERIKIA AND IDA VALLEYS.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
10	29/2/32	1.892	.541	.139	.436	71.4	20	Omakau
105	12/5/32	1.341	.367	.058	.214	72.6	24	"
88	15/3/32	1.468	.403	.092	.335	72.6	28	Lauder
85	13/2/32	2.611	.584	.058	.259	77.6	22	"
104	9/4/32	3.698	.945	.033	.127	74.4	22	Poolburn
22	21/4/32	2.378	.622	.045	.170	73.8	20	Lauder
94	2/5/32	2.256	.588	.068	.261	74.0	20	Ida Valley
8	13/4/32	4.681	1.149	.010	.042	76.4	20	"

Manuherikia Valley is a depression stretching south-west, mainly determined by two great faults, one along the east side of Dunstan Range and the other along the west side of Raggedy Range. The surface of the valley is covered with terrace-gravels, except where inliers of schist or of Tertiary beds are exposed or where hills of greywacke conglomerate rise above the terraces.

Ida Valley is similarly determined by two faults, but terraces are not so conspicuous as they are in the other basins, the higher ground of the floor sloping down gradually to the flood-plains of the Poolburn and the Idaburn.

The Manuherikia Valley is one of the driest districts in Central Otago, with an average rainfall of about 15 inches. Thyroid glands from these valleys contain a relatively high average of iodine, and there appears to be no tendency to thyroid enlargement.

TABLE IX.

EAST COAST—PALMERSTON TO OAMARU.

Lab. No.	Date.	Fresh Wgt. Grams.	Dry Wgt. Grams.	% I. Fresh.	% I. Dry.	% Moisture.	No. of Lobes.	Place.
†2	5/2/31	3.851	1.307	.087	.256	66.1	24	Waikouaiti
41	27/5/32	2.287	.623	.084	.308	72.7	12	Dunback
42	27/5/32	2.618	.660	.034	.135	74.8	14	"
44	30/5/32	2.509	.869	.106	.306	65.3	12	Kartigi
†13B	18/3/32	5.704	1.485	.073	.280	74.0	18	Moeraki Est., Hampden
13A	18/3/32	4.004	1.027	.044	.171	74.7	20	"
*34	20/5/32	2.944	.790	.047	.174	73.2	12	Reay Farm, Hubert
13C	23/4/32	4.126	1.094	.103	.388	73.5	16	Hampden
13D	23/4/32	3.862	.947	.041	.166	75.5	24	"
*28	13/5/32	4.041	1.168	.108	.373	71.1	20	Maruakoa
40	26/5/32	2.665	.789	.100	.337	70.4	12	Maruakoa
†36	23/5/32	6.665	1.856	.044	.159	72.2	12	Tapui
39	26/5/32	3.269	.851	.031	.118	74.0	12	Maruakoa
45	31/5/32	3.310	.831	.039	.155	74.9	12	Tokaiaki
23	23/4/32	2.754	.716	.068	.262	74.0	24	Weston
19	19/4/32	1.887	.532	.079	.280	71.8	20	Ngapara
35	20/5/32	3.452	.975	.059	.208	71.8	12	Pakopino
*18C	16/5/32	6.990	2.033	.108	.370	70.9	10	Oamaru
WAITAKI RIVER.								
12	18/3/32	2.297	.580	.071	.280	74.7	16	Waitaki
11	18/3/32	4.665	1.115	.021	.087	76.1	20	Duntroon
†37	23/5/32	5.231	1.477	.075	.264	71.8	12	Kurow

† Full-grown sheep. * Access to iodised licks.

The soils in this area are very varied, being on the whole light and good, with some alluvial schist and clay. The country is from hilly to rough and rocky. Less attention is paid to topdressing than in Southland, small amounts of superphosphate or lime being used occasionally. The rainfall is relatively low (20-30 inches), and the percentage of iodine in the glands well above the critical value. There is no indication of any tendency to thyroid enlargement in this area.

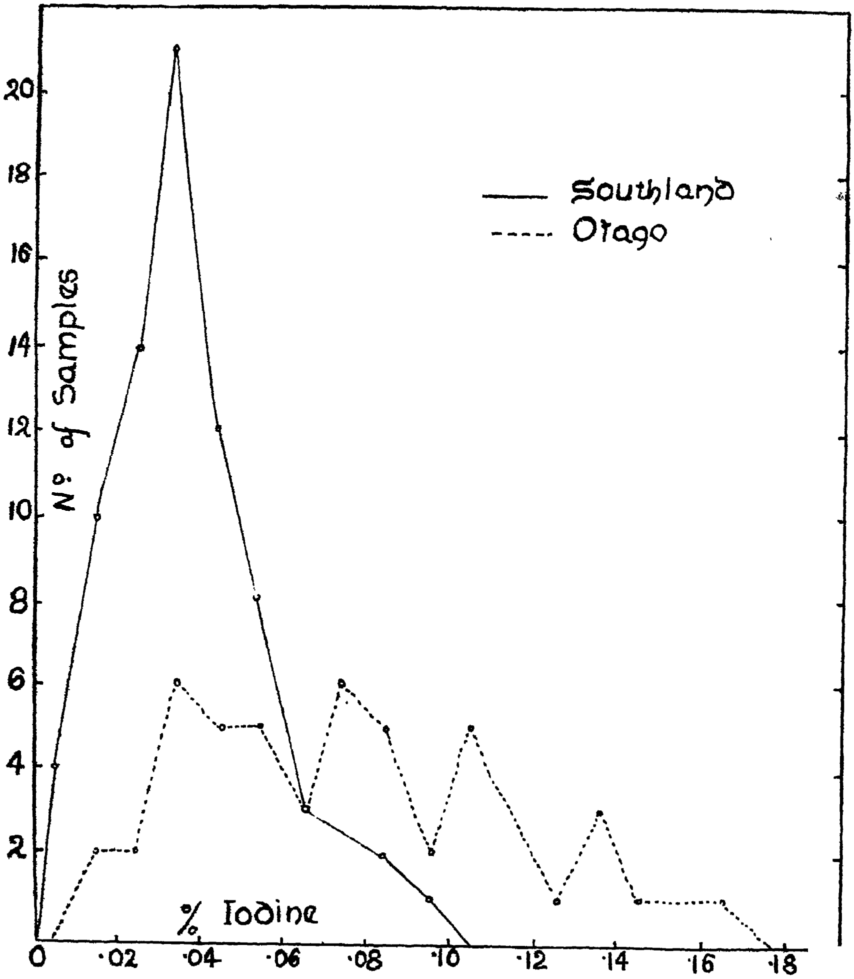

FIG. VII.

NOTE.—In Fig. VII, percentage of iodine is that calculated on the fresh weight basis, and the samples are those listed in the preceding tables. Glands from animals which have had access to iodised licks have been excluded. Under Southland are included the samples listed in Tables II, III, IV, V, and VI, and under Otago are those from Tables VII, VIII, and IX.

The curve for the Otago samples, apart from a jaggedness which is probably due to an insufficient number of samples, shows a fairly symmetrical distribution. Contrasting sharply with this is the curve for the Southland samples, which is decidedly skew in respect to the normal. This curve indicates clearly the relatively low iodine content of thyroid glands from sheep in Southland.

SUMMARY AND CONCLUSION.

A large number of samples of thyroid glands from sheep and lambs from Otago and Southland, New Zealand, have been collected, weighed, and analysed for iodine. The results have been classified according to district and listed in tables.

The relative effects of age, sex, and moisture on the percentage of iodine in the glands have been studied, but the data are as yet too scanty for the successful application of statistical methods, hence apparent variations may be due to chance only.

From a study of the weight of the gland and its percentage iodine, it has been shown that there is an inverse relationship, which is, however, almost negligible until the percentage of iodine has fallen below a certain critical value (0.03% fresh weight). Below this value the weight of the gland increases fairly rapidly, with a decrease in the percentage of iodine. Spontaneous enlargement of the glands may occur where the percentage of iodine is less than 0.03; these glands sometimes increase in weight fiftyfold. No such enlargement has been observed in any district where the percentage of iodine is above the critical value. It occurs usually in individual cases in flocks where the average percentage of iodine in the glands is below 0.03, though occasionally the whole flock is affected.

One case occurred at Wanaka (Hopkirk and Dayus, 1930) where there was an outbreak of congenital goitre among the lambs, all of which were born very weak, with much enlarged thyroids, while many were hairless or deformed. If the lambs survived three days, cures were usually effected by treatment with tincture of iodine. Salt licks containing 3 ounces potassium iodide per cwt. of salt have successfully prevented further trouble.

No explanation is offered of the phenomenon of a sudden outbreak of goitre, either in individual cases or in whole flocks, but there is undoubtedly some factor which affects the mechanism that controls cell proliferation and colloid storage, and throws it out of adjustment when the iodine in the gland is below a certain value.

Circumstances under which a deficiency is likely to occur are to some extent dependent on soil and climatic conditions. Light and sandy soils, accompanied by more or less heavy rainfall, facilitate the leaching of soluble salts, whereas the presence of heavy clays and loams or of good clay or rock substrata inhibits this effect.

In the semi-arid districts, where evaporation takes place rapidly, soluble salts are deposited in the soil where they are available for plant assimilation. In some districts these salts are exuded from small basin-like depressions in the ground, as salt incrustations which are directly available to stock. Hercus and others (1931) have found as much as 9000 γ iodine per kgm. in these deposits. Thyroid glands of sheep from these districts are rarely deficient in iodine

Old river flats are generally well leached, hence deficient in iodine.

From the data given in this paper it would appear that iodine feeding, with the exception of one or two cases, has little or no effect on the iodine content of the glands of sheep. As the total iodine of the thyroid can be increased by feeding iodides (Orr and Leitch, 1929), it follows that the sheep in question are not receiving an adequate amount. Therefore either they are not eating the lick in sufficient quantities or the iodides have been lost by leaching, decomposition, or some other means. At least one case has been reported in which the potassium iodide has decomposed and free iodine has volatilised in considerable quantities.

Potassium iodide is not stable under acid conditions, and therefore might be attacked by the carbon dioxide of the air or by traces of phosphoric acid in the salt. Inclusion of small amounts of lime or sodium carbonate should prevent its decomposition. Potassium iodide is also a very soluble salt, and thus might be easily leached away if the licks were exposed unprotected in the fields. Work is required on the efficacy of potassium biniodate in salt licks in raising the iodine content of thyroid glands, as this compound is considerably less soluble, and is more stable to acids.

Goitre is liable to occur in most of the Southland districts, so that the incorporation of iodides in salt licks as a preventive measure is to be advised.

Roughly, most of the country north of Dunedin and Alexandra, with the exception of the Lake districts, is free from the effects of an iodine deficiency, so that the use of iodised licks is only necessary in exceptional cases.

Until quite recently salt licks containing about 3 ozs. of potassium iodide per cwt. have been in fairly general use in New Zealand. Such large amounts of iodine have a therapeutic value in deficient areas, but it is doubtful whether they are necessary in general licks for preventive purposes. Experimental work with iodised licks under farming conditions is now in progress in some of the Southland districts.

The author wishes to express her indebtedness to Mr B. C. Aston for his valuable constructive criticisms throughout the work, to Mr C. V. S. Dayus and his field officers for the time and trouble they have spent in obtaining samples, together with the information concerning each.

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OBITUARY.

Karl Ritter von Goebel (1855-1932).

ALTHOUGH it will be many years before the New Zealand Institute can claim equality with the great academies of the world, in one respect it can vie with the best of them: in its long roll of honorary members. Indeed the list includes many of the greatest names in science of the nineteenth and twentieth centuries. Among such names, that of von Goebel comes into the small band of the truly illustrious. It is not my intention here to say much concerning the work achieved and the honours won by the great botanist; these have been reviewed in the leading scientific journals of the world, and the general reader may be referred to the admirable and generous account by Professor F. O. Bower in *Nature*, October 29, 1932.

Rather, I confine my remarks to some of the doings of von Goebel when he visited this country in November and December, 1898, and to my impressions of him both as botanist and man, formed during the inspiring botanical excursion I had the extreme honour to make with him in that interesting country traversed by the famous " West Coast Road." Also he—to the great pleasure of my wife and myself—made our home at New Brighton his headquarters during his stay in Canterbury.

May I say at once that I look on von Goebel as the greatest botanist of the last fifty years, and among the very first of the few who have stamped their names indelibly on botanical science by means of fundamental discoveries. As a young man he found plant morphology a formal and uninspiring branch of the science, but as early as the date of his Australasian tour he had made it a living thing, based not on mere classification and theoretical conjectures, but on a wealth of experiment carried out mainly by himself, and on the all-important field observations he had made in the Venezuelan Andes, the Malayan Islands, Ceylon, and Europe in general. The chief innovation of his studies was that he dealt with plant forms not as forms merely, but in relation to their environment, and such forms he deemed not mere members of the plant body, but organs.

At the time of von Goebel's visit I was attempting to shed some light on the causes which have led to seedlings differing from adults, and in my little greenhouse had dozens of flower-pots containing seedlings of many species of New Zealand plants grown from seed the origin of which was definitely known. Into this little house I conducted him on the day of his arrival, and this raising of seedlings—a work after von Goebel's own heart—led him to consider me a botanist, and formed the beginning of a true friendship which endured to the day of his lamentable decease. Perhaps that which interested him most was a simple experiment—the growing of a juvenile plant of " wild Irishman " *(Discaria toumatou)* in moist air under a bell-glass, the spines being suppressed and only leafy shoots produced. In my garden itself were herbaceous perennials from many lands, and with hardly an exception von Goebel not only knew their names, but could tell a great deal about them, a circumstance which surprises me more now than it did then, since I have met many botanists who know little or nothing about gardens and their contents.

During our mountain excursion we travelled along the West Coast Road by coach, staying in the first place for some days at the Castle Hill Hotel, since burnt down. Amongst other things the notable visitor desired greatly to procure a " vegetable sheep " *(Raoulia eximia)* of goodly size for his museum, and to take a part in its capture. Mr W. Cloudesly, proprietor of the hotel, his son, and a gay Irish " new chum " volunteered to do the hard work—the digging up of the sheep and its carrying down the steep mountain slopes with their insecure footing. The party ascended Mount Torlesse by way of the Dry River, and at an altitude of about 5000 feet a large flock of the sheep was encountered. The accompanying photograph shows the specimen as it arrived at the hotel, but better still on the left of the picture is von Goebel himself, with a " lamb " on his shoulder.

Although the botanist was intensely interested in all the indigenous spermophytes and pteridophytes he saw, and especially with their varied forms, he was still more interested in their lowly relations, the liverworts—a family which he explained were of especial morphological interest, since their simple structure and their multiplicity of forms made them ideal for experimental morphology. It was in a moist gully at the base of the Mount Alexander massif in Westland, crowded with liverworts of every shape and size (many being giants of the family), that von Goebel's delight rose to the highest pitch. " Here," he cried, " were it possible for me, I would build a cottage and spend the rest of my life studying the bryophytes in this gully." There is no such remarkable gully in the Wellington Open Air Museum, but one have I selected which may serve to perpetuate in this country his honoured name. Later I was able to forward by parcel post many tins of our liverworts to Munich, where they were well cared for, grew vigorously, and became a source of great interest, as well as being useful both for experimental and teaching purposes.

Speaking of teaching, I questioned von Goebel regarding his lectures, and he informed me that the courses he gave were principally for junior students, and, if I remember rightly, commenced at 7 a.m. He also explained that, where possible, material for illustrating lectures should be of large size. So, for this purpose, he took with him from the New Brighton Beach a huge example of the great seaweed, *Macrosystis pyrifera.* At the head of the Otira Gorge, where we camped for some days, he collected the giant moss *Polytrichum dendroides,* saying he wished to carry out a little experiment as to the power of its vessels to conduct water to the leaves. In the small room to the right of the old biological laboratory at Canterbury College the experiment was carried out. Professor Dendy was asked for various stains, none of which he possessed, so the experimenter said: " We will use ink," and ink he did use. Seated on a low stool, smoking a huge cigar, a small towel on his knees, with a razor in the right hand, he carried all out in the twinkling of an eye. But space is lacking for any more details regarding that, to me, most wonderful excursion.

As for the man—he was then forty-three years of age (one month older than myself). He was over six feet in height, stoutly built, his forehead high and broad, his face strong but gentle, and his hair and beard light brown, as became a South German. Full of scientific energy to his finger-tips, no time did he waste, but nevertheless a strong sense of humour was with him always. His disposition was of exceeding kindness, his learning most profound, his memory astonishing, especially regarding botanical literature in general, and withal he was modest to a fault. He spoke many European languages, and could read still more. He was widely read in literature generally, and loved and understood music. In that great monument which he created for himself, the three editions of his *Organographie der Pflanzen* (only the first edition is translated into English, so much is lost to the average English student), there is much that concerns New Zealand botanists, for example after example is given of New Zealand forms; in fact our flora gets more than its share of notice. As for the work itself, its author considered it would never be widely read, especially in these days when physiology dominates the botanical curriculum; but in a recent letter to me he prophesied that this state of affairs would end before long, and morphology once again come into its rightful place.

To me von Goebel's visit was the greatest scientific stimulus to my botanical career, such as it has been. Never before had I understood what a truly great man really was, and to be in the company of such in the field day by day is education of the highest order. Nor is this all, for to my immense advantage we were in close correspondence for thirty-three years (really our first letters dated from the early 'nineties, at which time he sent me his wonderful *Biologische Schilderungen*), and I was encouraged to come to him for advice at all times.

New Zealand has benefited from the visits of many scientific men, but, if Sir Joseph Hooker be excepted, no visiting botanist will have exercised a more enduring influence upon the study of our plants, in which morphology stands supreme, than von Goebel. For surely in this land of ours, where Nature has worked undisturbed century by century, the study of epharmony, that is, of open-air morphology, should be the chief concern of the field botanist for many years to come.

L. COCKAYNE.

Ngaio, January 28, 1933.

Arrival of the "vegetable sheep" for Munich at Castle Hill. Near the sheep the three "musterers" who carried it from the main spur of Mount Torlesse (5000 feet). On the left is von Goebel with a "lamb" on his shoulder.
—Photo. L. Cockayne.

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By PROFESSOR W. N. BENSON, University of Otago.

[*Read before the Otago Institute, 12th July, 1932; received by Editor, 8th October, 1932; issued separately, October, 1933.*]

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HISTORICAL INTRODUCTION.

The region to be described lies in the extreme south-west of New Zealand. It first came under the notice of Europeans on March 25, 1773, when Captain Cook, approaching New Zealand on his second great voyage, sighted the white cliffs of Chalky Island, but, as the coastline was " wholly obscured by a thick haze," stood out to sea again, and reached his objective, Dusky Sound, on the following day. Thirty years later sealing vessels began to frequent the coast, and its main features became known especially to a band of American sealers landed by the " General Gates," who, after seventeen months of misadventure near Preservation Inlet, were rescued in November, 1822, by a Sydney exploring schooner in charge of Edwardson, by whom a general examination was made of the recesses of Chalky Inlet. His results were communicated to M. de Blosseville, midshipman on a French exploring vessel, who published in 1826 a comprehensive account of the region, together with a map on which appear some of the present names for the salient features.*

The detailed survey of the coastline was made in 1849-51 under Captain Stokes of the H.M.S. Acheron, the surgeon of which vessel made the first geological examination of the region (C. Forbes, 1855). The occurrence of pink granites forming the ranges, flanked by metamorphic and steeply dipping " dark blue trap with a slaty fracture " forming the islands in Preservation Inlet, and underlying the coal-bearing sandstones and grits on Coal Island, was noted by this observer, and details were given concerning the occurrence and character of the coal. The origin of the " rift-like harbours " or sounds northwards from here is referred to the cracking of the crust consequent on the elevation of a ridge along an axis running some distance inland from the west coast, while to the presence of a parallel ridge adjacent to the coast is ascribed the origin of the thresholds at the mouths of these deep sounds.

Further studies were made in June and July of 1863 by Hector, who noted the main geological formations, indicating their general distribution on his manuscript map of Otago (1864) which is preserved in the Geological Museum of Otago University, and in which (a) contorted and foliated schists, (b) granite, and (c) brown coal formations are the three categories concerned. He paid special attention to the coal seams at Coal Island and Gulches Head, but was unable to land on Cavern Head, where later in the same year the first gold-bearing reef was discovered (fide McKay, 1896). Hector's account is, however, noteworthy as being the first statement of the production of hanging valleys as the result of glaciation, the effects of which were recognised around the region herein discussed. Observations tending to indicate coastal depression and others indicating coastal elevation were also recorded.

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* Most of these were doubtless supplied by his informants, but three of purely French origin were probably proposed by himself. Two, Presqu'île le Chevalier (now C. Providence) and Presqu'île Bréauté (the Treble Mountain Peninsula) have not survived, but the name Point Puysegur may perhaps have been used in honour of the French navigator A.-H.-A. de Puységur (1752-1809), though no explanation was given by de Blosseville. Edwardson was keenly interested in the birds of the district, and de Blosseville's name Bras Canaris may recall the abundance of such songsters. The name Cunaris used on the Admiralty chart for the same feature would thus appear to have been derived by an error in transcription.

Hutton visited the region ten years later, and gave (Hutton, 1875) a rather more precise account of its features. He recognised the occurrence in a neighbouring region of gneisses and mica schist which he classed as the Manapouri Series of presumably Archaean age. The argillites and clay slates noted by him were referred to an early Palaeozoic Kaikoura Series, and it was remarked that the granite sharply invaded these, producing but small contact metamorphism, whence it was inferred that the intrusion of the granite was definitely later than the formation of the Kaikoura sediments, and was much later than, and in no way connected with, the dynamic metamorphism of the rocks of the Manapouri Series. Contact-specimens of slate and granite collected by him were described and analysed by Liversidge (1877-1884). Hutton gave additional details concerning the coal measures, inferring their Tertiary age in the absence of fossils from the resinous character of the coal. Confirmation was adduced for the former glaciation of the region by noting the abundance of granite erratics in areas of Palaeozoic and Tertiary rock. Hector's deductions as to the subsidence of the region were held to be unconvincing, but additional evidence was found for regional uplift in the extensive series of terraces extending for many miles eastward from Puysegur Point. In 1889 Hutton described (as syenites) two granite erratics from Kisbee Beach, and his petrographical notes upon the rocks of the area have been briefly amended and extended by Hutton (1899), Marshall (1907), and Speight (1910).

In 1887 Reischek explored the north-western portion of this region, i.e., that lying between Northport and Dusky Sound, discovered several lakes and described other topographic features. An attempt made late in the " eighties " to settle a Scottish fishing community at Cromarty in Preservation Inlet proved unsuccessful, but in 1889 alluvial gold was found for the first time in exploitable amount on Coal Island, the region was surveyed trigonometrically (Johnstone, 1889), and a small " rush " set in, the working of the alluvium leading to the discovery of small reefs on Crayfish Island and larger ore bodies at the " Morning Star " Claim, near Long Beach or " Te Oneroa," at the " Golden Site " on Wilson River, and at Sealers' Creek, while a complex gold-, silver-, lead-, and copper-bearing reef occurring in granite was developed on Isthmus Sound. It is stated that in 1890 five hundred miners were on the field, and two hundred were there at the time of the visit of the Government Mining Inspector (Gordon, 1893). For a short time, it is said, about two thousand ounces of gold were obtained per month. This activity was, however, of short duration, and gloomy reports were soon current. A more optimistic view was, however, held by Carrick, who spent sixteen weeks exploring the region, reports of gold occurring in the neighbourhood of Cunaris Sound and of the head of Edwardson Sound being made by him. An abstract of his reports and a copy of his sketch map of the region were published by the Department of Mines (Gordon, 1895). By 1896, however, scarcely forty miners remained in the district. The " Golden Site " had lost its lode, and the " Morning Star " was in difficulties (McKay, 1896). A small amount of mining continued spasmodically for nearly twenty years more (see Inspecting Engineer's Reports, 1893-1913). In 1930 only one prospector remained, with the exception of the staff of the Puysegur Point lighthouse, the sole inhabitant of the region. The old workings are in ruins and all tracks are overgrown.

A detailed investigation of the geology and topography of the region was made by McKay in January-April, 1896, who gave most attention to the area eastward from Preservation Inlet to Big River, and examined the shores of Preservation and Chalky Inlets more cursorily. With the latter, therefore, the present investigations are particularly concerned. McKay followed Hutton in assuming the Archaean age of the metamorphic rocks north-east of the granite belt. On the west side of this he found " Lower Silurian " graptolites in two places among the graphitic argillites and sandstones in which the auriferous reefs were situated, but apparently brought back no specimens of these fossils. He also noted that the upper members of the Tertiary coal-bearing series were marly shales which, a short distance south-east from Puysegur Point, contained fossiliferous concretions with large specimens of *Ostrea*. He found also that locally auriferous glacial deposits extend over the plateau areas which slope regularly from a height of about 1000 feet down to the coastal cliffs on the mainland and on Coal Island, and held that they had been resorted by wave action and that the coastline had been elevated to the present height, this post-glacial movement having been followed by the deep dissection of the moraine-covered platform. Small locally-developed auriferous beaches raised to a height of 50 feet indicate the last phase of this elevatory movement. A systematic account of the topography and the former extent of the glaciers was also given.

In 1903 Andrews studied the physiography of the West Coast Sounds, and his observations on the region about Preservation Inlet are scattered through a group of papers (Andrews, 1905, 1906, 1907, 1911). He held that the sounds were pre-glacial valleys cut by river action in an elevated plateau, which rises north-eastwards from its lowest elevation near Preservation Inlet. These valleys were greatly enlarged and deepened by glacial erosion, the deepening being most marked at points of constriction and convergence, while erosion was greatly diminished and the sounds consequently are shallow where they broaden and diverge, Preservation Inlet being taken as typical of this feature. Tectonic movements and subsidence, he thought, played no part in their formation. Later (with Speight, 1910) he became doubtful of the correctness of assigning to glaciation alone the responsibility for the vast enlargement of the pre-glacial valleys, and considered that these depressions in part might be tectonic. The region now under consideration was thus described by him:—

" Preservation Inlet, New Zealand. Here a long and fairly shallow inlet, dotted over with islands, runs up along its lower portion into a plateau about 1000 feet in height, while its upper portion runs among much higher plateau remnants. The various topographies are separated by rough youthful forms. Heavy glaciers have passed down the inlet or sound, bearing moraines and other signs of ice action in various places. The most feasible explanation is that earth forces have raised a peneplain here in recent times to form two high plateaus, and dropped a centre block to form the inlet, which has since been modified by ice-erosion. . . . The long and profound cañons discharging into the fiords may easily be explained by erosive processes alone " (Andrews, 1911, p. 134).

A collection of graptolites made by J. S. Nicol (probably from the spoil-heap of the " Morning Star " mine) was described by Dr T. S. Hall (1915), who recognised therein the basal Ordovician forms *Clonograptus tenellus, C. tenellus* var. *callavei, Tetragraptus decipiens* and *Bryograptus* sp., characteristic of the Lancefield series in Victoria.

In 1921 Professor Park grouped the various sedimentary formations in Fiordland into three main divisions, holding that they are disposed in parallel zones dipping south-westwards, and accordingly are of decreasing age when traced westward. These are the Dusky Sound Series of presumably pre-Cambrian intensely metamorphosed schists, to the west of which lies the less altered possibly Cambrian Maniototo Series, invaded by batholiths which separate it from the westernmost and youngest series, the Preservation Inlet Series, of Lower Ordovician argillites and greywackes. The Dusky Sound Series if a definitely pre-Ordovician Series is apparently unrepresented in the area herein discussed, but by inference it may be assumed that Professor Park would have placed the schists northeast of the granites in Long Sound at least in part in his Maniototo Series, and in part, perhaps, in his Dusky Sound Series also.

In 1922 Park announced the discovery at Cape Providence of graptolite clay-slates co-eval with those of Golden Ridge in northwest Nelson, and higher in the Lower Ordovician than those of the " Morning Star " mine. He concluded that the Ordovician rocks in this region were arranged in a series of close-packed asymmetric folds with a general westerly dip. In 1927 Keble determined eighteen species in the material collected by Professor Park, and confirmed generally his determination of their age, pointing out its equivalence to that of the C_4 zone in the lower portion of the Castlemaine Series of Victoria as then understood. No indication was, however, seen of the presence of forms characteristic of the Bendigo Zone, which intervenes between the Lancefield and Castlemaine Zones of Victoria. The search for such beds was the principal object of the recent expedition.

All earlier reports thus clearly indicated Preservation Inlet as a region favourable for the search for additional graptolite-bearing strata, and for a study of the tectonics of the Ordovician rocks and their relationship to the metamorphic formations and of the geomorphology of fiords. Accordingly, with the assistance of a Government Research Grant of £150 obtained through the New Zealand Institute, an expedition was organised by the present writer wherein geological teachers from three of the New Zealand University Colleges might co-operate with a geologist experienced in the study of Australian Ordovician rocks. Through the courtesy of the Chief Secretary of Victoria, permission to join the party was obtained for Mr R. A. Keble, F.G.S., Palaeontologist to National Museum, Melbourne. Professor Bartrum, of Auckland University College, and Mr L. C. King, M.Sc., F.G.S., of Victoria University College, Wellington, with the writer completed the scientific party. Special acknowledgment must be made of the unstinted helpfulness of Mr Charles Yunge, the captain-owner of the schooner that conveyed the expedition, to whose enthusiastic interest in the work, local knowledge, and seamanship is due much of the success of the venture. The party sailed from the Bluff on January 11, but was weatherbound for some days at Stewart Island. Preservation Inlet was entered on January 20, and the party returned to the Bluff four weeks later. During that interval about a hundred miles of coastline were studied, but time did not permit the investigation of the thickly forested region away from the coast, of which McKay's account with slight emendation is herein accepted. The authorship of the statement of the results has been shared. This introduction and the general account of the geology and tectonics has been written by Benson on behalf of all members and with their criticism. Part II, dealing with the geomorphology, is the joint work of Benson, Bartrum, and King; Part III (petrology) that of Benson and Bartrum; and Part IV (detailed Ordovician stratigraphy and description of the graptolites) that of Benson and Keble. Except as regards the descriptive palaeontology, the manuscripts have been prepared by Benson, and after mutual discussion edited by Bartrum. The scenic plates are from Bartrum's photographs, the illustrations of the graptolites were prepared by Keble, and the remainder of the drawings and maps by Benson.

Grateful acknowledgment must here be made of the help given by Dr Marshall, and Professors Park and Speight in lending for comparative study microscope-slides of rocks from Preservation Inlet, the Green Islets, and Dusky Sound. Dr F. J. Turner also lent the whole of the material studied by him in connection with his petrological investigations in the Haast and Cascade Valleys, and helpfully discussed various points that arose. Through the courtesy of the Surveyor-General permission was granted for the use of Mr T. W. Preston's recently completed but unpublished map of Dusky Sound.

GENERAL SUMMARY.

(a) Topography:

The region investigated comprises three topographic elements (see Plate 41). There is a much-dissected highland rising to accordant summit levels, which decline from 4300 feet in the north-eastern corner to 3300 feet a few miles from the coast. Hereinafter the highland surface, of which the peaks represent the last remnants, will be termed the maturely dissected Fiordland Peneplain. Near the sea the land drops rather rapidly to 1500 feet, whence there extends a youthfully dissected coastal plateau sloping often convexly towards the coast-line five or ten miles distant, where it ends in a sea-cliff 100 feet to 400 feet high. Crossing the coastal plateau are two major inlets, Chalky and Preservation Inlets, representing the third topographic element, each partly closed by a large island, Chalky and Coal Islands respectively, covered wholly or in large part by thick Tertiary sediments. The surface of both of these islands is a continuation of that of the coastal plateau, though smaller islands which do not rise to the height of that surface lie further within each inlet. Dividing the two inlets one from the other is Gulches Head, a tied island, almost severed from the mainland by the embayment of Southport. From either inlet a long, deep, and narrow fiord with characteristic threshold extends into the region of the Fiordland Peneplain, broadly rectilinear in both cases, and, in the case of Chalky Inlet, dividing into two branches, Edwardson and Cunaris Sounds respectively.

(b) Stratigraphy:

Introductory Summary.

Apart from a partial cover of glacial and other post-Tertiary débris, the region studied is composed essentially of a very thick series of fine-grained, closely-folded Lower Ordovician sediments, invaded medially by great batholiths of granitic rocks elongated in a direction approximately N.W.-S.E., and injected with the accompaniment of thrust from the west, with resulting regional and contact-metamorphism of the sediments which became folded in the same orogeny. Above them, on their south-west side, there is a relatively narrow N.W.-S.E. coastal belt of Tertiary sediments, which locally also cover protruding granite. Just north-east of the line of trend of the inner margin of this belt, Lower Ordovician graphitic slates contain a fine sequence of graptolite faunules, which disappear north-eastwards with the increase of metamorphism on closer approach to the batholithic granite.

In the north-east corner of the region, at the head of Long Sound, there is a series of calc-silicate and other metamorphic rocks in which calcareous layers have been prominent in the original sediments, and which display intensely complex small-scale folds. The age of this Long Sound Series is indefinite, but evidence will later be presented in favour of its being Upper Ordovician and metamorphosed prior to the date of the batholithic injection. As a late effect of this injection, various quartz veins were formed by escaping solutions, and were involved in a general westerly-directed movement of thrust of a date subsequent to the earlier eastward thrust.

As will be shown in the appended summary of the stratigraphic and tectonic characters of the various formations, Tertiary sedimentation was preceded by a vast unrepresented interval, and has been followed by certain interesting tectonic movements.

Fossiliferous Ordovician Rocks.

The Ordovician rocks occur in their least altered form near Cape Providence, in the northern part of Gulches Peninsula, and about Preservation Inlet. They may be traced thence passing with increasing metamorphism northward along the shores of Chalky Inlet and Edwardson Sound, and thence eastwards by way of Cunaris Sound to the middle portion of Long Sound, where they are highly metamorphosed schists. They lie in simple, open folds on the western shores of Cape Providence (see Plate 42A), but in more tightly compressed folds about Preservation Inlet, and still more so in Chalky Inlet and its branches and in Long Sound. These folds, though not overturned, are often asymmetrical with their axial planes dipping steeply towards the west. The stratigraphical succession has been determined palaeontologically by the discovery of over thirty fossiliferous localities, sixteen on Cape Providence, thirteen on the southern shores of Preservation Inlet, two on the north-western shores of this inlet, and one on the northern part of Gulches Peninsula. From these, over eighty species of graptolites were obtained, most of which are identical with Victorian forms, though sixteen are new. Their relative position in the sequence is in general clear on stratigraphic grounds, and the successive faunal assemblages agree with those of Victoria. There are also several sponges provisionally referred to *Protospongia* and *Stephanella* (?), undetermined phyllocarids, and an obscure obolid (?) brachiopod. In a previous paper (Keble and Benson, 1928) the Lower Ordovician rocks of New Zealand were grouped tentatively into two major series, which we shall now term "Divisions." Of these, the lower was left unnamed, and comprised the "Preservation Zone," now recognised as the equivalent of the Lancefieldian Series of Victoria, and also the then undiscovered equivalent of the Bendigonian Series of Victoria. The higher or Aorere Division contained the Golden Ridge and Douglas Series, the equivalents respectively of the Castlemanian and Darriwillian Series of Victoria. As a result of the present investigations, the equivalent of the Bendigonian Series has been found, and the name Fiordland Division is suggested for the lower major Division, thus containing the New Zealand representatives of the Lancefieldian and Bendigonian Series. Moreover, it is now possible to recognise two zones in the Lancefieldian and three, or perhaps four, in the Bendigonian. Two zones may be distinguished in the Castlemainian beds, and the presence of a third is indicated by material obtained from pebbles. In order to avoid unnecessary duplication of stratigraphical names, the Victorian series-names will be employed to denote their precise equivalents in New Zealand.

The Lower Ordovician sediments comprise quartzite, greywacke, and grey or black carbonaceous graptolitic argillite. Even the least altered rocks show the first traces of metamorphism by the development of spots in the responsive pelitic layers. Occasionally a little calcite or siderite occurs in the argillite.

Intrusive Plutonic Rocks.

The Ordovician rocks described above have been invaded by a series of batholiths, about which is both regional and contact metamorphism. The batholiths lie for the most part in the outer portions of the region showing contact-metamorphism, so that their contact along their south-western borders is with slightly altered sediments, while that on their north-eastern margins is with strongly schistose metamorphosed sedimentary rocks. From the petrological viewpoint, the former constitute the upper and the latter the lower metamorphic zone, a contrast which, it will appear, has considerable tectonic significance. The batholiths consist chiefly of granodiorite and granite, but there is also a small sill-like mass of norite.

Metamorphism of the Lower Ordovician Rocks.

Metamorphic changes of regional character are displayed by the development of spotted phyllites, fine and more coarsely granular mica-schists, and porphyroblastic mica-schists and paragneisses. The more pelitic formations yielded readily to lateral compression, and highly schistose rocks resulted, whilst the greywackes tended rather to recrystallize statically with preservation of their original sedimentary structures, including lamination and current bedding, but with entire change of their original microscopic features. These changes are traceable with increasing intensity northwards and eastwards to the heads of Edwardson and Cunaris Sounds and into the middle part of Long Sound. Here, interbedded with schists and paragneisses, are relatively thin bands of calc-silicate hornfels-schists. Here, too, are the lower contact-metamorphosed schists.

Long Sound Series (? Upper Ordovician) and its Tectonics.

The north-east extremity of Long Sound shows sediments, apparently of a different type from elsewhere, in intensely crumpled beds, which appear to be overthrust to the north-east and enter into lit-par-lit contact with invading granodiorite. Petrologically they are feldspathic quartzites, calc-silicate hornfels-schists, and rarely mica-schists which were originally greywacke, marl, and mudstone, and there are unmistakable points of analogy with the rocks at Last Cove, further west in the same sound. For reasons to be advanced, these rocks are provisionally held to be Upper Ordovician sediments crumpled and overthrust before batholithic granitic intrusions that came up from the south-west during a phase of easterly-directed thrust, invading the almost meridionally folded sediments. The last expression of this compressional movement after the consolidation of the batholiths was overthrust faulting in the same direction represented by the Last Cove Fault.

Tectonic movements subsequent to the above suggest the action of the reverse member of the thrusting couple, namely, an overthrusting westward among the formations in the higher metamorphic zones, with the production of low-angle thrust-planes, as well as several series of nearly vertical fracture or shatter lines, along which differential movements took place, which caused movement relatively to the east on the north side of each fracture.

Quartz Veins, Minor Basic Intrusions.

The development of more or less mineralised quartz veins occurred just before and during the last movements. Apart from the apophyses obviously related to the batholithic intrusions, and the norite, the age and affinities of which are as yet indeterminate, there have been observed a sill of dolerite and a dyke of lamprophyre.

Tertiary Sediments and Their Structure:

After a prolonged unrecorded interval came the deposition of Tertiary sediments, beginning with arkosic basal conglomerates, sands, and mudstones accumulated in confluent fans and deltas, and incorporating swamp deposits containing small coal seams. These were covered by more sands and mudstones, followed, as the submergence became deeper, by thick marly sediments containing foraminifera.

Warping followed along N.W.-S.E. axes crossed by that along N.E.-S.W. axes. This was succeeded by the complicated sequences of geographic changes, culminating in the Pleistocene glaciation, that have determined the modern topography. These are discussed in detail in Part II.

PRELIMINARY ACCOUNT OF THE LOWER ORDOVICIAN STRATIGRAPHY AND FAUNAL SUCCESSION.

Detailed account of the stratigraphy of the Lower Ordovician rocks must await the final results of the examination (now almost completed) of the large collections of fossils obtained from these beds. Provisional study of these, however, has yielded results so consistent, both with the apparent stratigraphical succession in this region and with the known faunal succession in Victoria (Harris and Keble, 1931), that a preliminary statement of them is authorised by Mr Keble, who has the palaeontological investigations in hand, and has prepared the following explanatory paragraph.

"It is proposed to form two divisions in the Lower Ordovician rocks of New Zealand. The older, the unnamed 'series' in an earlier paper (Keble and Benson, 1929), will be termed the Fiordland Division, the younger or Aorere 'series' will become the Aorere Division.* The Fiordland Division presents that phase of graptolite development in which dichotomy is the dominant character and thecal specialisation is less evident, while of the Aorere Division the reverse is true. The Fiordland Division has been subdivided into two series, equivalent respectively to the Lancefieldian and Bendigonian Series of Victoria, for which, if New Zealand names are required, the terms Preservation and Dark Cloud Series† might be suggested. The Lancefieldian (or Preservation) Series is the lower, and common to it are forms in which dichotomy occurs at irregular intervals; in *Bryograptus, Clonograptus,* and even in some forms of *Tetragraptus* the dichotomising character is often recessive, stolonal thecae only appearing at intervals during which one or more brachial thecae are developed. Under such conditions the resulting polypary is unsymmetrical. On the other hand, in the Bendigonian (or Dark Cloud) Series, dichotomy is consecutive, and the branches, arising from the stolonal thecae, usually grouped nearest to the sicula, form a polypary both symmetrical and balanced; characteristic of this series are *Tetragraptus (sensu stricto), Dichograptus, Goniograptus,* etc. The lower, Castlemainian (or Golden Ridge) Series of the Aorere Division is marked by the development of *Didymograptus caduceus* in its multiplicity of mutations resulting from thecal specialisation and phylogenetic development, and towards its close by the appearance of such biserial forms as *Diplograptus, Trigonograptus,* etc. In the upper Dariwillian (or Douglas) Series of the Aorere Division the biserial forms are doubtless much more evident, and herald the approach of that character as the dominant feature of the Upper Ordovician rocks, the Mt. Arthur Division."‡

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* In the paper of 1929 the Preservation and Lancefield beds were referred to "zones," but Harris and Keble (1931) have reverted to Hall's use of the term "series" for the latter, and a consequent change has here been made in the naming of the New Zealand beds. It appears desirable to postpone the systematic application of the ordinal terms "series," "stage," and "zone" to various portions of the Ordovician system in New Zealand until more detailed palaeontological data are available. Meanwhile the terms "series" and "zone" are used herein in the same sense as they are now applied to the Victorian beds (Harris and Keble, 1931), in which no divisions corresponding in ordinal rank to the Fiordland and Aorere Divisions have yet been instituted.

The type section of the region is that running along the coast north-west of Cape Providence. It is confirmed and supplemented in some respects by the more strongly folded beds traced along the southern shore of Preservation Inlet from Kisbee Beach to Coal Island. The lowest beds are exposed a mile and a-half north-west of Cape Providence, where they are but gently flexed (see Plate III, Fig. A), perhaps also on the northern end of Gulches Peninsula, and again between Kisbee and Te Oneroa Beaches, at the north-east corner of Coal Island, and in Te Whara, in Preservation Inlet. In all but the first locality the beds dip steeply. These beds belong to the Lancefieldian Series, of which a thickness of nearly 3000 feet is exposed above concealed underlying formations. The lower portion may be correlated with the L3 zone of the Victorian Lower Ordovician beds. It is characterised by the presence of *Tetragraptus decipiens* T. S. Hall, with a very subordinate development of *Dictyonema macgillivrayi* T. S. Hall, *Clonograptus* cf. *magnificus* Pritchard, *Bryograptus clarkei* T. S. Hall, *Bryograptus victoriae* T. S. Hall, and seven other forms. The higher portion, best displayed between Kisbee and Powell's Beaches, is characterised by the association of *T. decipiens* T. S. Hall, with an abundance of *Bryograptus pauxillus* sp. nov. and *Clonograptus kingi* sp. nov., and sixteen other forms.

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† Commemorating Captain Cook's alternative name for Chalky Inlet.

‡ This remains true, though recent Victorian investigations indicate that it is desirable to transfer to the base of the Upper Ordovician the richly fossiliferous Cobb beds of the Mt. Arthur region, which were formerly considered the highest member of the Darriwillian (Douglas) Series. See Thomas and Keble, 1933, pp. 42 and 54.

This portion of the succession seems comparable with the L2 zone in Victoria. No faunal assemblage such as that in the L1 zone of Victoria has yet been found in New Zealand.

Two hundred feet above the highest fossiliferous horizon in the series last described, there occurs a bed containing *Tetragraptus fruticosus* (J. Hall), the index species of the Bendigonian Series of Victoria. It here displays the early four branched form, and is accompanied by *Tetragraptus approximatus* Nich., and *Tetragraptus acclinans* Keble, the association characteristic of the lowest or B5 zone of the Bendigonian Series, together with eighteen other species. This assemblage is partially displayed a mile north of Cape Providence, and more fully between Kisbee and Powell's Beaches in the south-eastern corner of Preservation Inlet.

The equivalent of the B4 zone on the Victorian sequence has not been seen *in situ,* but a boulder obtained nearly a mile north-west of Cape Providence showed the four-branched form of *T. fruticosus* (J. Hall) unaccompanied by *T. acclinans* Keble, *T. approximatus* Nich., or *T. decipiens* T. S. Hall, but with *Goniograptus macer* T. S. Hall, an association which would characterise the B4 zone in Victoria. This zone must, however, be very thin here, for three hundred feet above the B5 fauna there is a bed containing the three-branched form of *T. fruticosus* (J. Hall), a great abundance of *Phyllograptus typus* J. Hall, and thirteen other species, forming an assemblage which would be found in the B2 zone in Victoria.

One to two hundred feet higher still the three-branched form of *T. fruticosus* (J. Hall) is associated with *Didymograptus bifidus (sensu lato),* together with twenty-six other species, constituting an assemblage which is characteristic of the B1 or highest zone of the Bendigonian Series of Victoria. Thus the presence of four out of the five zones in the Bendigonian Series hitherto unknown in New Zealand would seem to have been demonstrated. It is to be noted that they are comprised within a thickness of 600 feet of strata, while in Victoria the equivalent strata are generally more than 2000 feet thick. The Bendigonian beds on Cape Providence consist of argillites and greywackes, and are bent into a broad synclinal fold, the characteristic B2 fauna appearing on either side of the axis, while the central portion of the syncline is occupied by Castlemainian beds.

The equivalents of the Castlemainian Series of Victoria have long been known in New Zealand, and from their presence in the northern portion in the South Island they were termed the Golden Ridge Series. They were first found in the south-west of the island, at Cape Providence, by Professor Park (1922). His collection, according to verbal accounts kindly given to the writer, was obtained from a spot about half a mile north-west of the cape. Nineteen species were recognised therein by Keble (1927), who referred the collection to the C4 zone of the Castlemainian Series as then understood. Additional material has now been obtained. In the axial portion of the abovementioned syncline, about one hundred feet above the highest bed yielding Bendigonian fossils and a thousand yards north-west of the cape, there are beds which are free from *T. fruticosus*

(J. Hall), but contain an abundance of *D. bifidus (sensu lato)* associated with a small form of *Isograptus caduceus* (Salter) = *I. gibberulus* (Nich.), *Dichograptus octobrachiatus* (J. Hall), *Tetragraptus serra* (Brongn.), *T. similis* (J. Hall), and sixteen other species, an assemblage which would characterise the basal Castlemainian zone C5, to the upper portion of which Professor Park's collection should now be referred. A similar association of fifteen species occurs in a richly fossiliferous bed on the northern shore of Coal Island, lying in regular sequence above fossiliferous Bendigonian and Lancefieldian beds.

The central portion of the syncline on the western side of Cape Providence is occupied by sparsely fossiliferous beds in which the dominant form is *Isograptus caduceus* (Salter), mostly small, but tending to become larger. "*D. bifidus*" no longer occurs, but *D. dependulus* H. and K. is present together with *Tetragraptus woodi* Rued. and a Diplograptid, an association of forms which may be correlated with that in the C4 zone in Victoria, as now defined by Harris and Keble (1931).

Among the pebbles gathered from the Cape Providence beach are graptolites from almost all of the above zones, but the presence of *Loganograptus logani* (J. Hall) in one pebble and of a large form of *Isograptus caduceus* (Salter) in others, both obtained from the eastern or Landing Bay side of the point, indicate that Upper Castlemainian beds belonging to the C2 or C1 zones must occur in the vicinity.

The total thickness of proved Castlemainian beds is about two hundred feet, but the presence of the two species last mentioned indicates that the actual thickness in this region may be considerably greater. There is no sign of the presence of any Darriwillian forms, or other forms derived from any higher series.

It thus appears that collections obtained from both sides of the syncline on Cape Providence, and in regular stratigraphic sequence along the southern shores of Preservation Inlet, have been shown to contain the same faunal zones as have been determined in Australian rocks, the very clearly displayed structural relationships of the several beds affording a most satisfactory check on the correctness of the faunal succession.

UNFOSSILIFEROUS AND METAMORPHIC ORDOVICIAN ROCKS.

Leaving for fuller description in Part IV the typical sections of fossiliferous Ordovician strata, attention may be turned to the unfossiliferous and metamorphic formations associated with them. The petrographical nature of their rocks is discussed in Part III, but their field occurrence will be noted here. The four principal types of sediment are quartzite, greywacke, grey argillite, and carbonaceous black argillite. Commencing in the least altered regions, Crayfish Island exhibits these four types of rock, the greywackes on its west coast displaying both current-bedding and ripple-marking. The strike is generally N.N.W. with a steep westerly dip, but at the northern end of the island . . . "the rocks have been greatly disturbed, and are seen striking directly across the general trend of the

(Ordovician) belt of country" (McKay, 1896), whilst shatter zones running slightly north of due east traverse them. In Long Island jointed quartzites and greywackes alternate with graphitic slates showing strain-slip cleavage. Round Island consists of shattered quartz-veined siliceous greywackes, and the Cording Islets of quartzites, grey and spotted argillites. The last show considerable disturbance of the line of strike, and are broken across by several sets of shatter-zones. North of Kisbee Bay a sequence of contact-metamorphosed rocks was obtained by Keble, including quartzose biotite hornfelses derived from greywackes, and cordierite hornfelses derived from argillite. The latter, when in the immediate vicinity of the intrusive granite, show extremely well-developed and abundant cordierite, and similar rocks were collected by Marshall in 1930 from glacial erratics at Te Oneroa Beach. On the eastern side of the entrance to Isthmus Sound, Hutton (1875, p. 40) observed masses of slate included in the granite with slight alteration at the immediate contact. The line of contact passes through the north-easternmost part of the Cording Islets on the western side of the entrance, and appears to be displaced laterally by a fault. In Brokenshore Bay greywackes are in contact with a coarse granite, rich in pink orthoclase, along a very sharply defined and irregular boundary. On the northern shore of the bay the greywacke becomes lighter in colour adjacent to the granite and more coarsely crystallized, and near the junction is almost indistinguishable from granodiorite, which, in fact, intervenes in small amount between the granite and the greywacke, making an undetected contact with the latter. Traced westward, the metamorphism rapidly diminishes, but the more responsive argillites are here scantily developed. At Rounding Head, between Brokenshore Bay and Cuttle Cove, a band of argillite appears to have been changed with the development of cordierite, now entirely replaced by quartz. Nearer the cove a narrow diorite dyke is fringed with a well-crystallized biotite hornfels. The rarity of argillite bands and of preservation of bedding planes renders impossible a detailed study of the folding suffered by the beds here, but a sharp anticline is exposed south-west of Cuttle Cove, where spotted argillites occur. At Cavern Head the massive quartzites are broken by a series of quartz-filled tear-veins running in a east-north-east direction, and adjacent thereto there is local deflection of the general meridional strike into a north-east direction, probably as a result of drag along this line of tearing. The rocks showing this disturbed strike are intermediate in character between argillites and quartzites, and nearby is a zone of graphitic micaceous argillite containing a formerly exploited quartz reef. Near the beach north-west of Cavern Head, Hector (1863) noted a dyke of porphyritic granite invading the argillite. A series of finely-bedded, locally puckered argillite or fissile shale, shattered greywacke, and quartzite extends between Cuttle Cove and Seek Cove, and forms also the Spit Islands, Te Whara, near which graptolites of the Lancefield series occur. These rocks are thrown into sharp folds and broken by shatter or shear-zones parallel or oblique to the strike, whilst the increasing development of sericite gives a phyllitic appearance to the argillite. The change is more marked at the eastern side of the entrance to Southport, where the rocks are clearly subschistose and contain spotted bands. This schistosity results from the development of sericite with flakes of biotite more or less changed into chlorite, and is particularly well displayed in Garden Island and the eastern portion of the islets to the north of it, where the rock is a pale greenish or brownish, silky sericite-schist, slightly sheared or puckered, and resembles the schist of Central Otago more nearly than any other formation in the Preservation Inlet district. On the eastern half of the northern islet it is interstratified with a thin layer of amphibolite, and dips westward at at angle of about 35°, but the western half of the islet consists of a mass of intensely sheared or mylonitised schist dipping steeply westward at 62° and containing abundant long slickensided lenticles of quartz. This mass strikes in a meridional direction, and marks an important fault-zone with down-throw to the west, which is here called the Southport Fault, and extends through the strait west of Garden Island, and probably along the eastern shore of Gulches Peninsula. The northern portion of this peninsula, meanwhile, consists of perfectly normal quartzite, greywacke, and argillite containing obscure graptolites, sponges, and phyllocarids. Its horizon is uncertain.

Continuing northwards along the coast of Chalky Inlet, the schistose character of the argillite and the spotting become more evident, though the associated greywacke shows clearly current-bedding and ripple-marking, and at a point near Surf Head irregular crumpling of lamination resulting from slumping of the sediments during their accumulation is clearly displayed. Hector (1863) very appropriately described these rocks as " . . . an interesting group of siliceous felstones, greenstones, glossy claystones, and mica-schists." The structural features observed during this northward traverse are a swinging of the regional strike from a meridional into a north-east direction, the presence of a syncline and the occurrence of several vertical, approximately east-west shatter zones.

New features appear at the entrance to Cunaris Sound. Crystals of biotite about half a millimetre in diameter have developed in the recrystallisation of the finer greywackes, while the base has become either granulitic or schistose and sericitic, and, traced northwards into Edwardson Sound or eastward along Cunaris Sound, these petrological features become so strongly evident that the rocks appear like fine-grained gneisses, and were so termed by Hector, though mistaken for granite by Linck. They may be termed porphyroblastic paragneisses. Their metamorphism has been very largely the result of recrystallization under static conditions, for on some weathered surfaces they still display original current-bedding, unobliterated by development of schistosity, just as clearly as do the unaltered rocks on Cape Providence, with which they seem to have been identical. In other cases it is evident that the rocks had been shattered and sheared before subsequent recrystallization completely changed their microscopical structure, for thin sections and recently fractured surfaces give no hint of such major structures, though they are often clearly etched out by weathering. Interstratified with these rocks are typical biotite-sericite-schists, with well-developed schistosity usually parallel to the bedding plane. The spotted structures have considerable persistence, but become gradually obliterated in the formation of biotite-schist and paragneiss. Though there is an average increase in grain-size towards the east and north, there is great variation in this respect, and more or less finely laminar and fine and coarsely granular paragneisses are interbedded. In addition there are included quartzites, which are greenish, and tend to become vitreous by recrystallization. A peculiar layer consisting of sericitic quartz-amphibolite, probably derived from a band of dolomitic marl a few feet thick, has been noted at the head of Edwardson Sound and near the entrance of Cunaris Sound, and again near its head. At two or three points dykes of diorite or aplite radiating from the Treble Mountain massif reach the southern shore of Cunaris Sound, while the margin of the massif itself touches the shore of Islet Cove. Structurally it is to be noted that the strike of the sediments has returned to the meridional trend, and that a series of anticlinal and synclinal axes cross Cunaris Sound perpendicularly, whilst fault planes dipping east at low angles and overthrust to the west are visible at a number of places.

No geologist has traversed the valley of the Carrick River entering Cunaris Sound, but as Linck (1896) noted that the pebbles in its delta consist " . . . mainly of mica-schist, quartzose schists, and quartzites, with only a small percentage of granite," it appears probable that there is little plutonic rock in its watershed, and the Long Sound Series is well represented.

Save for the absence of plutonic apophyses, the rocks of the northern shore of Cunaris Sound are precisely the same as those on the south, though no correlation of individual bands has yet been possible. The same types of rock continue up the eastern shore of Edwardson Sound, where they show an alternation of rather glassy quartzites with a predominance of medium or fine-grained biotite-sericite-quartz-schists, and of porphyroblastic biotite-paragneisses of varying grain-size and degree of schistosity. Some bands are almost massive. In one instance it appeared possible that the schistosity was not parallel to the bedding planes of the original sediments. According to Linck, schistose rocks form the mountains on either side of Lake Cadman, an inference supported by their topography, whilst similar rocks also surround the head of Edwardson Sound. The strike of these schists swings almost into parallelism with Edwardson Sound, near Divide Head, but bends to the north and north-north-west nearer to the head of the sound.

The western coast of Edwardson Sound is almost rectilinear, and runs approximately parallel to the margin of the plutonic rocks of the adjacent batholith, whilst evidences of shearing can be noted both in the field and under the microscope in the rocks along this boundary. The most massive block of schist marginal to the granite is a narrow coastal strip, about a mile in length, situated about three miles south-west from the head of the sound. Its rocks are schists of medium to coarse grain-size associated with the usual paragneisses, but the appearance in them of large flakes of white mica is, however, a new feature resulting from contact-action. This latter is very marked along the shore further south-west, where, for two miles from the southern end of the main strip of schists, the contact between the igneous and metamorphic rocks is beautifully displayed on the glaciated surfaces of the low promontories as a zone of brecciation and interpenetration of schist by granite and ramifying veins of quartzose pegmatite, along which large fragments and strips of schist appear included in the granite. This has led to the development of very coarsely crystalline almost gneissic schists with large flakes of white mica as well as of biotite, whilst in certain layers at the contact there are grains of a bright yellow epidote (or clinozoisite), and locally some felspathisation has taken place. The rarity or indeed absence of garnetiferous schists is noteworthy. This mass of rocks will be referred to in Part III as the Edwardson intrusion complex.

Similar contact-schists occur on the southern portion of Little Island and the north-eastern part of Great Island, but it is uncertain whether or not they occur in the south-eastern part of Passage Island. Masses of schist also form large inclusions ramified by veins of diorite, granite, aplite, or pegmatite in the vicinity of Northport. They have been found in the valley of the stream draining Lake Cæsar, at the head of the cove by Mosquito Point, and in the promontory south of the western entrance to Northport (Blind Entrance). As frequent reference must be made to this locality, it will hereafter be termed Blind Point. At this locality the complex of schists and invading aplite and pegmatite is very involved. The strike of the schists has been deflected to the north-east, and their facies include felspathic quartz-chlorite schists and sillimanite-biotite schist, the latter with coarse epidote (or clinozoisite). Biotite schists also occur in large included masses at Lake Cæsar Creek, and are probably fragments of a large roof pendant or an infaulted strip of schist along the line of Northport fracture. They do not extend any distance to the north of this line, as the pebbles in Shallow River are all igneous. On the authority of two miners, Linck (1896) doubtfully indicated the presence of slate between Breaker Point and Landing Bay, but observations made during two traverses overland and from the sea make it probable that this area consists of granitic rocks.

The series of schists occurring in Cunaris Sound extends across the narrow isthmus into Last Cove in Long Sound, and continues eastward with increasing grain-size and schistosity. The most coarsely crystalline of the moderately and markedly poikiloblastic paragneisses, of the quartz schists, and of the mica schists occur along the north coast of the sound, extending three miles east of Last Cove. Here, as elsewhere, there is a close association of fine and coarsely granular schists, and the occasional retention of the original bedding planes made evident on the weathered surfaces of massive rocks. Schists may contain lenticular segregations or irregular bunches of quartz or thin laminae developed in the planes of schistosity, but the quartzites are either hard grey-blue almost glassy rocks, or micaceous and almost saccharoidal, both types being fractured and seamed by quartz-veins. Similar rocks form the promontory immediately south of Last Cove, but are interlaminated with calc-silicate hornfels-schist, which on weathered surface has a very characteristic fluted appearance. It forms here a narrow band in the normal biotite-schists, and the same is true of a layer occurring a mile east of Last Cove and of another five miles to the east-north-east on the islet between Only Island and the southern shore. These rocks must have been derived from layers of dolomitic marl within original sediments composed of laminae of varying composition. Their present nature is clearly the result of heating by adjacent intrusive masses, as well as of regional compression. A band of coarsely flaky biotite-sillimanite-schist with small " augen " of orthoclase, occurring adjacent to a slabby, finely granular mica schist a mile east of Last Cove, is also a product of deep-seated contact-metamorphism, as are also the coarse quartzose mica-schist, the knotted andalusite schsts, and pinite (?) schists on the southern shore of the sound adjacent to the granodiorites.

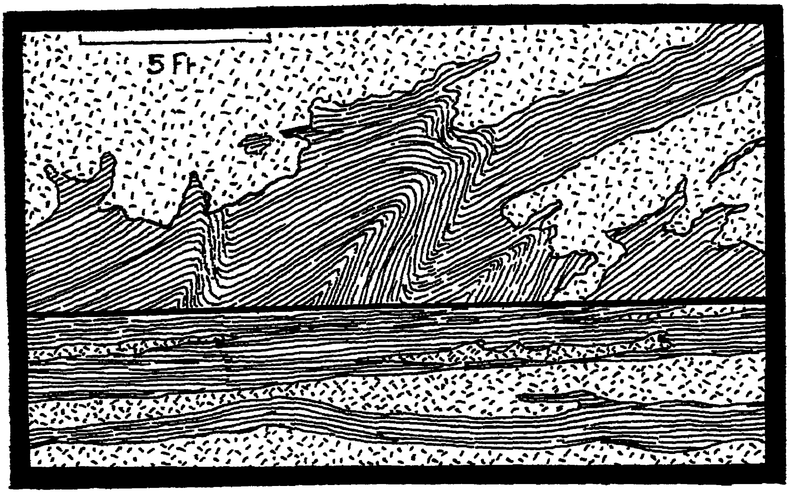
Injection-schists showing a very high degree of intensity of metamorphism occur about half a mile south of Only Island, in the headward portion of Long Sound, whilst the whole development of schists in the middle portion of this sound lies within the influence of plutonic intrusions, which occur in force on the southern shores, but are represented for about three miles of the northern shore only by an occasional dyke of aplite, granodiorite, or norite. Larger masses occur on either side of this length of shore and enter into lit-par-lit injection into the schists immediately west of Last Cove.

Structurally, all these schists dip very steeply either east or west of a strike line trending a little west of true north. They are cut off to the west by the Last Cove fault, which dips to the south-west at 50°, and by which the Treble Mountain granite massif has been thrust to the east. The clearly displayed passage of Ordovician sediments comprising fossiliferous beds into thermally and dynamically metamorphosed rocks finds close analogies among the formations of south-eastern New South Wales (Browne, 1914) and north-eastern Victoria (Tattam, 1929).

THE LONG SOUND SERIES.

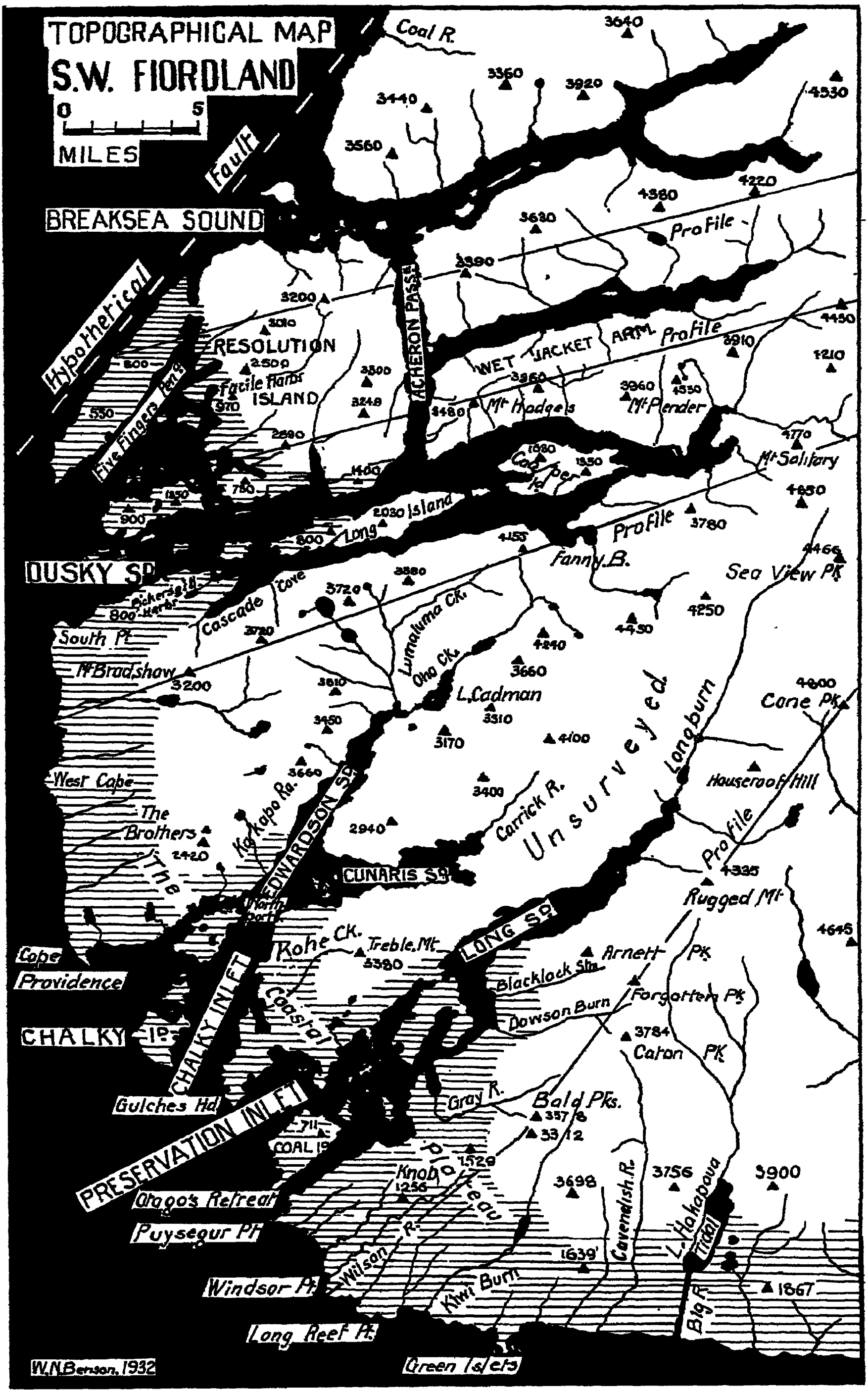
The rocks classed in this group extend for nearly two miles southward from the head of Long Sound, and have been examined most closely along the northern shore. They are probably a portion of the schists grouped by Hector as "mica-schists, feldspathic gneiss, and quartzites." In general of fine to medium grain-size, they are well laminated, alternate layers being largely quartzite, with scattered mica and thin streaks of felspars and calc-silicates, or grey speckled calc-silicate laminae consisting largely of minerals such as quartz, bytownite, diopside, ilmenite, and calcite, or grey-brown with abundant biotite. They weather into an ochreous or rusty mass. Their peculiar composition indicates their derivation from a series of sediments composed of alternating layers of feldspathic sandstone, dolomitic marls, and claystone. They now occur in close-packed folds broken by small faults and thrusts as illustrated in Plate 43B, a photograph taken a mile from the head of the sound. The folds are often overturned and almost recumbent, so that a cliff face about 1200 yards from the head of the sound exposing a number of such folds superposed one on another resembles a pile of folded blankets, each fold being from three to ten feet thick. On the east side of the head of the sound the cliff face of Houseroof Hill reveals on a larger scale the same intricate folding. Though it is unsafe to generalise from a small number of observations of dip in so highly disturbed a formation, the strike appears to be nearly meridional or to the east of north, the dip generally to the west at low angles, and the folds almost invariably overturned to the east. Striations on the exposed surface of the folds indicate some slipping in the direction of dip, whilst an appearance of striation perpendicular thereto arises from minor strain-slip movements parallel to the strike.

On their western limits the rocks of the Long Sound Series are cut off by granodiorite, which invades them in characteristic lit-par-lit injections, particularly well displayed in an isolated mass of these rocks in the cove immediately north of Only Island (see Text Fig. 1). Nowhere along the northern shore of Long Sound do these rocks come in contact with those described in the last section (p. 409). On its southern shore the evidence is even less clear. The crumpled schists of the Long Sound Series have been traced south along this shore to a promontory nearly two miles south of the head of the sound, and are then replaced for about a mile by plutonic rocks; these are followed in turn by a further mile of schists which continue to Only Island, where they show lit-par-lit invasion by granodiorite. The schists of this last portion of the coast showed no obvious lithological or structural difference from those further west, but adverse weather conditions did not permit of as close an examination of them as desirable, so that possibly here the relation between the Lower Ordovician sediments described in the last section and certain interesting calc-silicate rocks at Last Cove may be ascertained in the future.



Text Fig. 1.—*Lit-par-lit injection of granodiorite into the calc-silicate schists of the Long Sound Series. Observed on the north shore of Long Sound, opposite Only Island. Direction, left to right, is S.W. to N.E.*

There is, however, sufficient petrological evidence to suggest very strongly what that relation may be. As will be shown in Part III, the remarkable mineral composition of the siliceous Long Sound rocks, with their quartz, microcline, and diopside, is repeated by one of the bands of the calc-silicate hornfels-schist at Last Cove. The composition of the finely granulitic grey layers in the Long Sound rocks, with its quartz, basic plagioclase, diopside, ilmenite, and red-brown sphene, is repeated by a thin layer in the islet adjacent to Only Island, which has further petrological links with the Last Cove rocks. The micaceous layers among the Long Sound rocks and the quartzitic layers in the mass north of Only Island have also analogies among the schists near Last Cove. Obviously it is out of the question to correlate thin layers of calc-silicate rocks with the great thickness (a thousand feet or more) of the Long Sound Series. What is suggested, however, is that the calc-silicate rocks in the Ordovician schists of the middle part of Long Sound indicate the entry into the Ordovician sedimentation of a marly or calcareous phase that found fuller expression in marly quartzites, marls, and mudstones, which now have been converted into rocks of the Long Sound Series. In this connection reference may be made to Park's (1888) account of Cooper Island and the parts of Dusky Sound fifteen miles north, or along the line of strike from the head of Long Sound. The rocks are described as " granite gneiss which passes into felsitic schists, and contains beds of mica schist and crystalline limestone," or again as " coarse arenaceous mica schist passing into felsitic schist, which forms frequent transitions into or alternates with mica schist, quartzites, hornblende schists, chlorite schists, talc schists, and contains several bands of crystalline limestone." A " gneissic schist with orthoclase," recalling the augen schist of the area now described, is



Text Fig. 2.—*General map of the south-western portion of Fiordland, illustrating the dominant directions expressed, the probable extent of the Coastal Plateau, and the position of the profiles traced in a plate accompanying Part II of this work.*

also recorded, but the absence of any marked crumpling of the beds is noted. Their westerly dip is, however, at lower angles than that of the schist near the sea. As noted above, the watershed of Carrick River intervening between Dusky and Long Sounds appears to be occupied chiefly by schists, though their nature has not been ascertained, so that the continuity of the two more or less calcareous series of schists may be suggested. Moreover, occurrences of crystalline limestone are known in certain other of the northern sounds, viz., Doubtful, Thompson, Caswell, and Milford Sounds,* so that the former existence of an extensive calcareous formation among the schists of Fiordland is apparent. That it may continue further south is indicated by McKay's (1889) note of presence of marble in the north-western extremity of Stewart Island, and the occurrence of schistose calc-silicate hornfels forming a roof pendant in granite at the summit of Blaikie's Hill in southern Stewart Island. According to private communications from Dr G. J. Williams, who discovered this hornfels, its strike is parallel to that of the adjacent mica schists which also forms large roof-pendant masses. Petrologically, the calc-silicate hornfels shows the closest similarity to rocks of the Long Sound Series, an important fact the citation of which is permitted here through the courtesy of Dr. G. J. Williams. A massive calcareous series also (the Mt. Arthur Series) has long been known in association with the Ordovician sediments and schists in the northern extremity of the South Island of New Zealand, and correlation therewith of the southern calcareous rocks may be a reasonable working hypothesis. The relation of the Mt. Arthur rocks to the Lower Ordovician graptolitic sediments has long been in dispute, but the most recent work of the Geological Survey leads to the conclusion that the Mt. Arthur beds belong to the Upper Ordovician, and follow conformably the Lower Ordovician formations.†

Provisionally, therefore, it would appear to be possible that the intensely folded rocks of the Long Sound Series may result from the local crumpling of a series of Upper Ordovician sediments which have been involved in the region of most intense metamorphism. If so, it may be that the rocks of the supposedly pre-Cambrian Dusky Sound Series of Park (1921), to which these would be assigned on the basis of degree of metamorphism, comprise formations actually younger than the far less altered rocks of his Lower Ordovician Preservation Series (the Lancefieldian, Bendigonian, and Castlemainian Series of the present paper), but it is by no means proved yet that this is the case. The cause of the very marked easterly-directed crumpling of the Long Sound Series is considered in a later section.

THE INTRUSIVE ROCKS.

General Description.

The major occurrences of plutonic rocks fall into two larger and two smaller masses. The two larger may be termed respectively the Bald Peaks-Treble Mountain massif, which is divided by Long

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* See Morgan, P. G., 1927, p. 66, for references.

† See Keble and Benson, 1928, for statements based on Grange's field work.

Sound, and the Great Island-Kakapo Range massif, which is divided by Northport. So similar is the range of rocks in these two masses that they are probably united beneath Chalky Inlet. The granitic boss on Gulches Head is the third of these occurrences, and may be a cupola arising from the same great batholith as gave rise to the massifs mentioned above, the extension of which beneath the surface to the south and west is suggested by " spotting " and development of tourmaline in the Ordovician sediments there. The fourth mass, the Long Sound massif, crossing the middle portion of that sound, probably does not extend far to the north, as it is certainly not widespread in the watershed of Carrick River. On this view of the batholithic continuity of several of these plutonic masses, there are but two main intrusions—the huge, only partially deroofed Bald Peaks-Kakapo Range batholith and the far smaller Long Sound massif, which differs petrographically and structurally from the major one. The former lies in the main between the slightly altered and the strongly altered Ordovician sediments, and is elongated (as far as the area of the present map is concerned) in a north-west-south-east direction. The latter lies within the strongly altered rocks, and its orientation is unknown. The observations of the present expedition have been made only along the shore lines, and are, therefore, far from complete, but agree with the general features of differentiated batholiths, and are interpreted in accordance therewith.

Bald Peaks-Treble Mt. Massif.

The major portion of the Bald Peaks-Treble Mountain massif would appear to be a coarse-grained granite, with large pink orthoclase crystals—a handsome rock, which, as Marshall (1929) indicates, would form an excellent building stone, and could be quarried near deep sheltered bays. It forms the majority of the plutonic erratics between Kisbee Bay and Puysegur Point, and occurs in situ along the shores of Revolver and Useless Bays, Narrow Bend, and the southern part of Long Sound and most of Isthmus Sound. In the last region there are occasional inclusions of slate and of granodiorite and quartz-diorite. These last less acid rocks occur along its margin in the areas examined, but need not completely encircle it; they are strongly invaded by the granite, which may locally break through them and come into direct contact with the sediments. At the entrance to Isthmus Sound the rock in contact with the slate is granodiorite, according to an old chemical analysis (Liversidge, 1877), and at Brokenshore Bay, a little to the north-west from there, a very narrow mantle of granodiorite, strongly invaded by the granite, intervenes between the latter and the greywackes. Beyond this to the west, north-west, and north-east apophyses are known, dykes of diorite at Cuttle Cove and near Cunaris Islands, and of aplite near the entrance to Cliff Cove at the head of Cunaris Sound. Here, also, a steep bluff of diorite with diorite-pegmatite rises from near the water's edge, and in Cliff Cove itself a few yards of quartz-diorite-selvedge are exposed on the shore, the boundary of the granite extending thence to Long Sound. It is exceedingly significant that this steeply plunging margin of the batholith is cut off by a fault, which dips at 50° under the batholith, and that the movement of that fault, as shown by the drag of the schists on the footwall, should have been an easterly-directed overthrusting (Text Fig. 3).

Gulches Boss.

The Gulches boss has been little studied, though a rather fine-grained quartz-diorite rich in chlorite was noted alongside the fault between the inner and outer headlands of Gulches Head, and probably represents a marginal facies. According to Hector (1863), Red Head consists of coarsely crystalline granite with large flesh-red crystals of orthoclase, which doubtless represents the central acidic facies.

Great Island-Kakapo Range Massif.

The Great Island-Kakapo Range massif is separated from the boss at Gulches Head by Chalky Inlet. The nature of the granite rocks in Passage Island and in most of Great Island has not yet been ascertained, though the south-western promontory of the latter consists of a rather gneissic, porphyritic granite, with large red orthoclase crystals, which is veined by syenite-aplite. Near the beach at Landing Bay a quartz-syenite with large crystals of orthoclase invades in lit-par-lit fashion gneissic quartz-diorites and diorites, and is itself invaded by coarse pegmatite and siliceous biotite granite with slabby, modified basic inclusions. A few hundred yards north of the shore of this bay the valley of Lake Thomas Creek is cut in gneissic orthoclase-bearing granite, with foliation very well developed near its margin and directed N.37°W.

Suggestion that a roof-pendant or down-faulted portion of the roof of the batholith extend through the Northport area is afforded by the marginal character of the rocks therein. Gneissic diorites occur in force along the northern shore west of Mosquito Point, and the normal sequence of invasion is well displayed. Strongly gneissic amphibolite and diorite are invaded by granodiorite or aplite; granodiorite by granite, aplite, or pegmatite; granite by aplite and pegmatite. All these rocks have also been found invading schists. The pebbles in Shallow River, which are mostly of granite, show the same order of succession, and invasions of gneissic microdiorite by granodiorite and of both by aplite can be seen in a single pebble. The watershed of this stream appears to be wholly in igneous rocks, and two overland traverses between Lake Hector and Landing Bay showed only granite or granodiorite.

The eastern boundary of the Great Island-Kakapo Range massif is probably in part a fault, for north-east of Anchorage Cove gneissic granodiorite near the contact shows marked shearing. Elsewhere its border is a complex injection-breccia, wherein the marginal granite and granodiorite invade the schists irregularly or in lit-par-lit fashion, whilst masses of schist are included in the granite, the whole complex being seamed with ramifying veins of aplite and very quartzose pegmatite. The structure is well displayed on glaciated salients by the shore from one to two miles south of the small cove on the mid-western shore of Edwardson Sound, and attracted the attention of both Hector (1863) and Linck (1896). South of this, the massive cliffs facing the entrance to Cunaris Sound seem to consist of pink granite, and the same rock probably also forms the bare pinnacles of the Kakapo Range. Thus in this massif also, granodiorite and more basic rock-types seem to be confined to a narrow, marginal zone about an essentially granitic batholith.

The tectonic structure of the intrusive mass is not yet known, and, in particular, the direction of schistosity of the rocks near Edwardson Sound was not recorded, though it probably was north-east-south-west. That of the rocks near Northport was more nearly parallel to the length of that channel. If, then, the massif had in the main rectilinear boundaries along north-west-south-east and north-east-south-west directions, it would seem that, at the time of its intrusion, the folded Ordovician rocks had already been subdivided into blocks by two of the major fracture systems that are known throughout the region, trending diagonally to the general strike. Movements along these may have occurred at later periods and be illustrated possibly by trough-faulting along Chalky-Edwardson Sound itself.

Long Sound Massif.

The Long Sound massif is not well known, and its structure is possibly complex, though the total mass of plutonic rocks exposed may not be great. The section shown below the map (Plate 43) and Text Fig. 1 illustrate the conception formed of the occurrence, namely, that it is a small, broken, and irregular intrusion extending in a series of apophyses and lit-par-lit injections, which have been thrust mainly eastwards into the schists. Its western limit on the north shore of Long Sound appears to be along a fault about three miles east of Last Cove, though veins of granite and of aplite occur west of this fault. Lit-par-lit injections, both into the Lower Ordovician schists and into the rocks of the Long Sound Series, are well displayed on both sides of the sound near Only Island, whilst the igneous rock in turn contains many large inclusions of coarsely granular quartzose schist. The rocks of the massif are granodiorite or quartz-mica diorite, and rarely diorite, the invasion of the less siliceous by the more siliceous types being apparent in a number of cases. A dyke of coarse diorite-pegmatite invades the hornfelsic schists along the shore about a mile to the north-east of Only Island; gneissic structure is developed in it to some extent, but information as to its strike is very incomplete. In the lit-par-lit apophyses south of Only Island, however, the foliation dips at 80°E., with a strike N.33°E.

The Norite of Long Sound and Other Basic Intrusions.

The field-occurrence of the hornblende-norite early mentioned as outcropping in Long Sound is little known, as its plutonic nature was not recognised when the specimens were collected. It forms a small promontory by a waterfall on the north shore between two and a-half and three miles east of Last Cove, and thus midway between the latter and Only Island. As no indication of its making transgressive contacts was seen, it probably forms a sill-like intrusion. Petrological investigation shows that, though the rock is well jointed, it exhibits no evidence of gneissic structure or even of the strain-phenomena that are commonly present in the other plutonic rocks of the region. While, therefore, it may be related to the main series of batholithic rocks, it is possible that it belongs to a newer series of intrusions. Turner's (1930) work in the Cascade Valley immediately north of Fiordland has led him to the view that the gabbros and ultrabasic rocks of the Red Hills belong to a later period (early Cretaceous?) than the granite-diorite group of intrusions in Fiordland, which Hutton and Park (1921) have held to be Palaeozoic, though Speight (1910), followed by the writer, have referred them also tentatively to the early Cretaceous period of orogeny. The norite shows some vague analogies with the rather diverse plutonic rocks of the Bluff and Orepuki, and those closely associated with the granites-granodiorites and diorites in several places in Fiordland. Until more is known of the field-relations of these norites, the age of the Long Sound norite must also remain uncertain.

At the point immediately east of Te Oneroa, on the north-east shore of Otago's Retreat, a sill of ophitic dolerite, thirty feet thick and entirely without sign of strain-effect, invades quartzites against which it shows a fine-grained chilled margin.

The only other intrusive body to be noted here outcrops near the northernmost point of Coal Island as a band of ochreous, porcellanous rock, a few feet in thickness, which has proved to be a much altered lamprophyre, possibly analogous with the Early Tertiary (?) dykes of similar character occurring here and there throughout the Southern Alps.

THE QUARTZ VEINS.

The quartz veins fall into several classes:

(a) Veins forming an irregular stockwork following more or less along the strike of the enclosing formation are found either in the quartzites and siliceous greywackes on the one hand, or in the carbonaceous slates on the other. Such veins are specially abundant in the siliceous rocks near fold axes, the country rocks being here often intensely brecciated and riddled with small quartz veins, which are sometimes mineralised. McKay traced one such vein-aggregate through the Golden Site claim on Wilson's River, and another from the western end of Te Oneroa Beach, Otago's Retreat, through the north-eastern portion of Coal Island, where it forms "a network of small veins and leaders of quartz, which abound in pyrites and from which silver-bearing galena has been obtained." The "carbon slates" of the "Morning Star" Mine and other localities, such as Crayfish Island, contain similar veins.

(b) Quartz veins are less abundant in the crystalline schists and more apt to segregate into irregular masses or "blows." Such occur locally on the eastern shore of Edwardson Sound near Southport, and in Long Sound. On the southern shore of Cunaris Sound, two narrow veins were noted running north-west oblique to the general strike and containing, with chlorite and graphite, pyrite and chalcopyrite. Evidences of replacement of the country rock by quartz can be observed.

(c) & (d) Veins associated with dislocations of strata may roughly be divided into (c) those associated with flaw-faults and (d) those associated with low-angle thrust-faults. The former occur especially with those fracture-zones that dip at high angles and strike in general east-north-east-west-south-west direction, transecting the more nearly meridional veins. They occur especially near the shores of Preservation Inlet, and are well illustrated by the series of small tear-veins in Cavern Head. In 1863 it was reported that a reef in this region yielded on assay 37 ounces of gold per ton, but it was never rediscovered, and the report, if true, probably referred only to a small ore-shoot. Other vein-filled shatter-zones following the same direction occur in Crayfish Island and near Te Oneroa in Otago's Retreat; the most remarkable of them shows a mass of coarsely crystallised pale buff dolomite containing angular fragments of quartzite. Veins associated with low-angle thrusting are frequent along the shores of Cunaris Sound. The thrust-planes dip gently to the east or west, but the movement in every case is a westward displacement of the hanging wall by a few inches or feet. The planes are often, but not always, marked by quartz in films or layers an inch or more in thickness, sometimes bordered by green mica. Commonly they cut across steeply-dipping veins following the plane of schistosity of the country rock, which they may partly replace.

(e) The occurrence of saddle-reefs is suggested by a "back"* occurring to the east of Powell's Beach, which is in the small bay half a mile east of Te Oneroa, Otago's Retreat.

TECTONICS.

The tectonic features of the region present many contradictory features, and the problems connected therewith are as yet far from solved. In this section only those tectonic features of the Ordovician sediments, schists, and plutonic rocks are considered, the dislocation of Tertiary rocks being discussed in a later section.

Folds.

Intensity and Direction of Folding:

There is considerable diversity in the character of the folding, for the intensity of disturbance increases towards the east. On the western coast of Cape Providence the Ordovician rocks form broad, open anticlines and synclines with a gentle pitch towards the north-north-east. The promontory itself is apparently divided by a fault, and the rocks on the eastern side dip steeply to the west with a north-north-westerly strike. In Gulches Peninsula and from the southern parts of Preservation Inlet across Cunaris Sound to the head of Edwardson Sound, the rocks lie steeply dipping, arranged in a succession of closely folded anticlines and synclines, and are often so nearly vertical that the fold-axes cannot be distinguished. It is noticeable, however, that the westerly dips are often less steep than those directed to the east, indicating that the folding tends to be asymmetric with axial planes overturned eastwards (see Plate 43). The strike-direction is rather sinuous; in the main, slightly west of true north, it is occasionally a little east of that direction, and, south of the entrance to Cunaris Sound, swings into a north-east direction for a couple of miles, returning to its more nearly meridional trend north of that sound. Possibly the strike of the schists near Blind Entrance, Northport, and the direction of the pitching fold-axes on Cape Providence may reflect this broad inflection of the general line of strike. In the middle parts of Long Sound the same features are continued across from Cunaris Sound. Schists dipping almost vertically are widely extended, with a rather sinuous strike running slightly west of true north. Though this curvature of the strike characterises rocks wedged in between two great batholithic masses, it may not be wholly dependent on their intrusion, and was probably in existence before the rise of the magma into the upper levels of the crust, though perhaps this latter was a late effect of the same orogenic movement as caused the folding.

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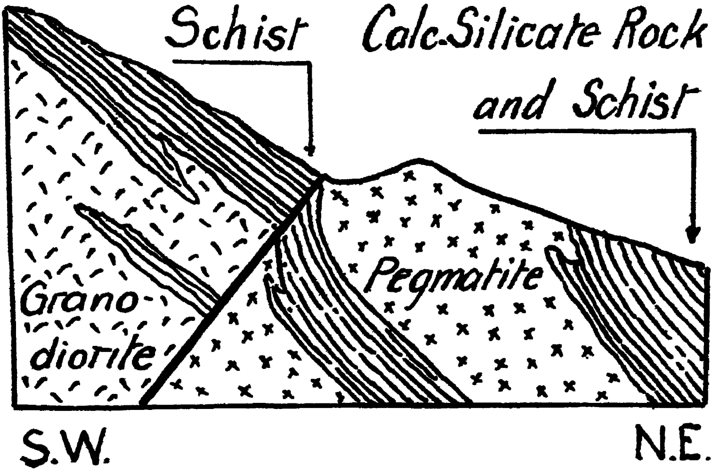
* "A 'back' used here as in Bendigo mining is a bedding plane along which there has been a slipping movement of the beds and a circulation of mineral solutions. It is marked by the presence of flucan or laminated quartz. The cap and legs of the saddle reefs usually form on the backs over the anticlines" (Stillwell, 1917).

At the head of Long Sound there are the intensely folded rocks of the Long Sound Series overthrust eastwards and with a strike that runs, on the average, rather east of north. Yet, if the correlation of these rocks with the calcareous formations in Dusky Sound holds good, this crumpling must be a local feature only, for it is not observable in the rocks of Dusky Sound according to Professor Park's explicit statement (1888; 1921). The same conclusion follows from the petrographically-supported comparison of the Long Sound Series with the calc-silicate hornfels-schist further west in the same sound at Last Cove and Only Island, and from the lack of any obvious break between rocks of the Last Cove facies and those of the Long Sound Series on the south-eastern shore of the sound, though it must be admitted that the sequence is here interrupted by many igneous intrusions. The evidence, though weak and inconclusive, is cumulative. The local nature of the intense crumpling is therefore accepted as a provisional hypothesis.

Faults.

(a) *Easterly-directed Fault-thrusts:*

One of the most striking features in regard to faulting evidenced in the region studied is the Last Cove Fault. This strikes north-west-south-east, and dips beneath the Treble Mountain batholith, showing by the drag of the schists along the footwall that it has been overthrust to the east (see Text Fig. 3). It has been shown in an earlier section that there is evidence that this batholith dips away to the south-west, underlying the normal Ordovician sediments there, that its contacts along its western side have the features of shallow-depth thermal metamorphism, and that those on its eastern side, by Last Cove and opposite thereto, have all the characteristics of contact activities at depth in their degree of dynamo-thermal metamorphism. The deduction seems reasonable that the Treble Mountain-Bald Peaks granitic mass is essentially laccolitic in nature, and rose into the crust as a result and accompaniment of easterly-directed thrust in the higher portions of the crust. The intrusion probably occurred during the later stages of the orogeny by which the invaded sediments were folded and regionally metamorphosed, though its actual date is uncertain. Under the compulsion of thrust from the west the deeper sediments appear to have been compacted in tightly pressed folds, whilst those at higher levels at first under a lesser load were thrust into a synclinal forefold, and there crumpled into a mass of small overfolds, such as characterise the Long Sound Series. Thus might arise a differential movement which would be likely to introduce a zone of shearing between the lower and upper series of beds, which would prepare an entry for uprising magma. The granodiorites and their associates of the Long Sound massif would appear to have been injected as a fringe in front of the Treble Mountain-Bald Peaks massif, and to have entered in lit-par-lit injections into the crumpling rocks of the Long Sound Series. Any major batholiths lying still further to the east beyond the head of Long Sound may perhaps be deemed to have risen as a consequence of the same general upward movement of magma within the crust, initiated by thrust towards the east, by which the plutonic complex of Fiordland was built up. When the plutonic activity died down it was followed



TEXT FIG. 3.—*Section across Last Cove Fault exposed on the north side of Long Sound.*

by the emission of siliceous solutions depositing in fractures the more or less mineralised quartz veins of the area. This closed the epoch of easterly-directed pressure and magmatic invasion, and prepared the scene for the next or westerly-directed movements.

(b) *Westerly-directed Movements:*

When these movements began, the region had probably passed from a geosynclinal stage, and with accompanying batholithic invasion had been elevated into a mountain range. Whether as a consequence of down-folding or foundering of blocks to the west or merely of up-arching of the range, necessitating that the earlier pressure from the west be transmitted through deeper layers, a thrust in the reverse or westerly direction now manifested itself at upper levels of the crust as an expansive movement compensatory to the strong compression at lower levels. Its magnitude may not have been great, but of its existence there is abundant evidence. In a large number of localities there appear planes of shearing or thrusting, dipping gently to the east and showing westerly displacement of the hanging walls to the extent of a few feet. Often this is most vividly clear, as when a nearly vertical quartz vein is cut across by such a thrust, and may be illustrated by mention of actual examples.

The easternmost of these is an almost horizontal thrust plane cutting off a wriggling quartz vein in the quartz-schist of the Long Sound Series north of Only Island in Long Sound. In Cliff Cove, at the head of Cunaris Sound, there are a number of low-angle thrust-planes, cutting across the ridge of a sharp anticline, the cap of which is overthrust to the west, as shown by the drag of the beds and the displacement of quartz veins. On the promontory facing the little islet at the entrance to Cliff Cove, a very marked thrust-plane appears dipping gently westward, but showing the westerly movement of the hanging wall very clearly, for the schists on either wall have been dragged, and there is a long, lenticular "horse" of crushed and slickensided rock enclosed between them.

A like feature was noted again nearly four miles further west along the southern shore of Cunaris Sound near a small islet, and there are a number of further examples displayed on the shores of Cunaris Islets. Again, on the shore of Chalky Inlet near Surf Point, the same feature occurs; the dip of the thrust-plane in this case is N.47°E. at a small angle, with westerly overthrust, though near at hand the dip of other westerly overthrust-faults may be as much as 45°. The rocks are, however, here strongly jointed, and the movements have been complicated by small relative displacements along several series of joints.

Fault and Fracture-Systems.

Systems of intersecting faults, shatter-belts, fractures,* and joints have long been regarded as of considerable significance in guiding the development of fiord topography. Attention was, therefore, directed to the evidence for the existence of such fracture-systems in the region described herein. It must be recognised, however, that records of the direction of the prominent fractures observed along the shores of any region cannot give a complete knowledge of the fracturing of the whole area. In some formations, often near the margin of granite-masses, there appears to be little definite arrangement of joints or fractures, probably as the result of the complex stresses set up by the processes of intrusion under pressure and of the diverse reaction to continued strain of the solidified igneous rocks and the invaded formations. The effect also of strains acting obliquely on such different rocks as quartzite and mica-schist may also result in complex and irregular fracturing. Further, it is obvious that, if sufficient angular variation be permitted, an infinite range of directions may be grouped into a few main trends. Nevertheless, there does seem to be sufficient evidence to suggest, if not entirely to justify, the grouping of the fractures in the Preservation Inlet region into four or five major systems. The evidence detailed below is entirely structural, but its possible connection with the principal topographic features will be considered in Part II.

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* The term "fracture" is here restricted to mean a plane of disruption along which there has been differential movement, but of unimportant amount.

(1) *Faults, fractures, and joint-planes trending nearly east and west (generally north of east):*

This is the most clearly marked series of fractures, and seems in the main to consist of a group of small flaw-faults running perpendicularly to the regional strike and more or less independent of its local sinuosities. The following are noteworthy examples. The quartzite bluffs immediately south-west of Te Oneroa, Otago's Retreat, are cut transversely by several fault-planes dipping steeply to the south-south-east, the northern block being moved eastwards relative to the southern in each determinable case. Fracture-zones trending north of east traverse the Ordovician rocks in Coal and Crayfish Islands. According to McKay, the strike of these rocks in the northern end of the latter island has been bent almost perpendicularly to its normal direction, as if dragged against a strong, eastward-moving flaw-fault. Similar conditions obtain in the western portion of the Cording Islets, and a fracture belonging to this series runs along the northern shore of the largest islet of this group, whilst the displacement of the boundary of the granite north of these islets suggests a fault in this east-west direction. Local deflection of the strike lines can be seen immediately east of Cavern Head, and this promontory itself has been cut by a series of tear-veins following a trend north of east. The strongly-marked jointing in the centre of the granite mass in the southern portion of Long Sound is again in the same direction, as is that of the granite near Only Island in the northern portion of that sound. The strong joints, which traverse Cape Providence and cut off the quartzite stack known as the Sugar-loaf, trend almost due east, whilst the jointing of the igneous rocks not far distant on the eastern shores of Landing Bay also run nearly east, as does that of the granite near Mosquito Point in Northport.

(2) *Faults, fractures, and joint-planes trending approximately north-east:*

These are strongly suggested by many topographic features, but the structural evidence for them is as yet scanty. There is a strong fracture-zone having this trend traversing the granite on the northern side of Long Sound opposite Only Island. In Preservation Inlet the jointing of the rocks on the eastern part of Brokenshore Bay, a fracture-zone traversing the easternmost of the Cording Islets, the fractures and joints that have guided the formation of the great chasm in Cavern Head, and a fracture observed a short distance east of Seek Cove belong to this group. The sluiced surface in Berg's claim at Te Oneroa shows fractures trending north-east, which cut across a strong fracture-zone running south of east and bring about a total displacement of the northern block of fifteen feet to the north-eastwards. The deflection of the plane of schistosity into this direction at the western entrance to Northport may be noted, and parallel thereto is the eastern margin of the Kakapo Range massif furnished by the west coast of Edwardson-Chalky Inlet, along which there is abundant petrological evidence of fracturing and granulation. A series of joints cutting through the Cunaris Islands follow approximately this direction. Finally, the fractures or joint-planes that may have been instrumental in guiding the formation of Otago's Retreat belong to this group.

(3) *Faults, fractures, and joint-planes trending west of north:*

This series of disjunctive planes is almost perpendicular to that first described and about parallel to the regional strike. It is represented by a set of joints in the granites of the northern part of Long Sound, by a very prominent group of fractures running through the Cording Islets, by the chief quartz-reefs on either side of Otago's Retreat, by a shatter-zone extending through Te Whara to the mainland, and by the Southport and Gulches Faults. The structural evidence for the Southport Fault is seen in the northernmost of the Garden Islets, of which the eastern portion consists of gently-dipping sericitic schists and amphibolite, while the western portion is composed of almost vertical, highly sheared quartz-sericite-chlorite schist with long lenticles of sheared quartz and mylonite. Further south this zone of shearing extends into the jagged reefs in the narrow strait between the gently-dipping sericitic schists of Garden Island to the east and the normal greywacke and argillites of Gulches Peninsula to the west, rocks of such utterly distinct facies as to indicate their separation at an early date by a most powerful fault, with a heavy westerly downthrow. The physiographic suggestion that the sea-cliffs along the west shore of Southport and their scarp-like south-east continuation represent a fault or fault-line scarp, may indicate movement at a much later date in a reverse direction along the same fault. The evidence for the existence of Gulches Fault is detailed below. Its latest movement was certainly subsequent to the formation of the Tertiary rocks, but probably previous to the latest movement of the Southport Fault. Finally, an approximately meridional trend is followed by a very well-marked series of joints in the folded Ordovician sediments north-west of Cape Providence.

(4) *North-west-south-east faulting:*

The only strongly-marked fault that trends north-west-south-east is the Last Cove Fault, which dips steeply to the south-west at 50° and shows eastward overthrust. It cuts through the selvedge of Treble Mountain granite massif. Well-developed jointing parallel to this trend is displayed by the schists about Lake Cove, at the head of Edwardson Sound.

(5) *East-south-east and other fractures:*

A small number of fractures run in an east-south-east direction. They include a shatter-zone passing through Berg's claim at Te Oneroa and displacing the northern block to the eastwards, another cutting through the Cording Islets and dipping at 80° northwards, and a third a little south of Stripe Head, north of the entrance to Southport. Joint-planes in the southern side of Passage Island seen from a distance apparently also follow this direction.

A shear-zone exposed on the southern shore of Cunaris Sound opposite the Cunaris Islands runs in a direction east of north. It dips steeply eastward, and is overthrust to the west. This would run perpendicularly to the last group of fractures, but is the only instance observed of a fracture following such a direction.

THE TERTIARY ROCKS.

General Description.

Fairly detailed accounts of these sediments have been given by previous writers, and the present expedition, therefore, devoted little attention to them. The basal members of the series vary considerably in thickness, and have been described by McKay as conglomerate-breccias associated with arkosic sandstones, with streaks of carbonaceous felspathic sandstone and mudstone. Near Puysegur Point the sandstone is interstratified with quartz conglomerate with subangular pebbles up to an inch in diameter. Hutton (1875) noted the presence of two seams of resinous brown coal up to three feet in thickness between the lighthouse on the extremity of the point and the boat-landing near it, just inside Otago's Retreat. On Coal Island, granite boulders up to thirty inches in diameter occur in the basal conglomerate, whilst the succeeding strata of arkosic sandstones and grit have interstratified carbonaceous layers with pyritic concretions and beds of grey mudstone containing obscure foraminifera. Between Gulches Head and Price's Beach the sediments are conglomeratic with angular or subangular boulders of granite, porphyry, hornfels, or rarely schist up to a foot in diameter, scattered through an arkosic groundmass or aggregated into impersistent layers. Similar rocks also form the northern portion of Chalky Island. These basal beds range from a hundred to six hundred feet in thickness, and are followed by flaggy sandstones with plant remains, which, on Coal Island, are about two hundred and fifty feet thick, and are succeeded by coarse grits and laminated sandstones on which coal seams rest. The seam observed by Hector on Coal Island was barely a foot thick, while that occurring at the same horizon on Gulches Head was from two to four feet thick, and may be represented also by a seam exposed near the shore west of Seek Cove. The composition of the coal according to analyses by W. Skey (Hutton, 1875; McKay, 1896) is illustrated below.

	(a)	(b)	(c)	(d)	(e)
Fixed Carbon - - - -	41.23	45.66	52.89	46.26	60.47
Volatile Hydrocarbons -	20.43	31.49	38.47	32.88	25.68
Water - - - - -	16.20	16.52	6.41	14.26	6.19
Sulphur - - - - -	5.40	n.d.	n.d.	n.d.	n.d.
Ash - - - - - -	7.74	4.53	2.23	6.60	8.70

(a) and (b) Gulches Head.
(c) Seek Cove.
(d) Coal Island (av. of three samples).
(e) Puysegur Pt. (av. of three samples).

In general it may be said that the coal is lenticular, and that the probability of any seam continuing for a long distance is small. The coal measures on Coal Island are overlain by clay-shales and sandstones, the total thickness of beds being estimated by Hector as about 1500 feet. Locally, as at the small pocket-beach on the western side of Otago's Retreat, the clay-shales contain a few obscure foraminifera. In Chalky Island the arkosic sandstone is about 3500 feet thick, and is followed by a hard grey marl which merges locally into impure limestone. The calcareous rocks are altogether 1200-1500 feet thick. Intercalated in them are many bands of arkose from a fraction of an inch to several feet in thickness, and layers of more sandy marls with worm-burrows, fucoid markings, and indefinite plant-remains. Several layers of foraminiferal material were observed in the marl, and specimens of this and of the arkose were forwarded to Mr W. J. Parr, of the Department of Mines, Melbourne, who has prepared a detailed account thereof, which will appear later. The writer is indebted to him for various letters from which the following facts are abstracted:—" The marly rock is not very richly foraminiferal, but a number of foraminifera have been found in the arkosic bands also, together with sponge spicules and fragments of polyzoa.

The following foraminifera have been recognised:

Marsipella elongata Norman, rare.
Ammodiscus sp. aff. *incertus* (d'Orbigny), rare.
Spiroplectammina parallela Cushman, 1.
Textularia sp., 1.
Vulvulina sp. aff. *pennatula* (Batsch), 1.
Verneuilina sp. aff. *bradyi* Cushman, 1.
Nodosaria sp. aff. *parexilis* Cushman and K. C. Stewart, 1.
Nodosaria antipodum Stache, rare.
Melonis pompiloides (Fitchel and Moll.), 1.
Elphidium sp. aff. *macellum* (Fichtel and Moll.), rare.
Gumbelina sp. cf. *globulosa* (Ehrenberg), rare.
Bulimina sp. cf. *pyrula* d'Orbigny, 1.
B. sp., 1.

Bolivina sp. A., rare.
B. sp. B., 1.
Uvigerina sp. aff. *interrupta* Brady, 1.
Rotalia sp. aff. *calcar* (d'Orbigny), 1.
Amphistegina sp. aff. *lessonii* d'Orbigny, common.
Pullenia sphaeroides (d'Orbigny), 1.
Globigerina sp. A., common.
G. sp. B., frequent.
Cibicides refulgens Montfort, common.
C. sp., rare.
Planorbulina sp., rare.
Halkyardia bartrumi sp. nov., common.
Gypsina sp. cf. *howchini* Chapman, 1.
Carpentaria proteiformis Goes, 1.

In addition to the foraminifera there are siliceous sponge spicules of the genera *Spirastrella ?, Geodites, Corallistes, Pachastrella,* and a Dictyonine hexactinellid. All of these forms have been recorded by Hinde and Holmes (1892) in the paper on the sponges from the Tertiary of Oamaru and also occur living.

The finding of *Halkyardia* can justly be described as of extraordinary interest, as this genus has hitherto been known only from beds of Eocene age in Dalmatia and at Biarritz. It is there similarly associated with *Amphistegina* and *Carpentaria.* Two species have been described, *H. ovata* (Halkyard) and *H. minima* (Lebius), the second of which is the nearer to *H. bartrumi* sp. nov. Judging from the occurrences in Chapman's (1926) monograph on New Zealand foraminifera, and from my own observations, the deposit is probably of Oligocene or Miocene age. In Australia, particularly in the Lower Beds at Muddy Creek, and in the Miocene at Table Cape, Tasmania, we have a similar occurrence of genera and species which are either identical with or closely related to forms which in Europe are confined to the Eocene."

No trace of mollusca could be found in the rocks forming the eastern cliffs of Chalky Island.

At Gates Harbour, four miles south-east of Puysegur Point, McKay found that chalky limestones rest on concretionary marly shale and soft sandstone overlying the basal coal-bearing conglomerate-breccia. The concretions are often fossiliferous, and in particular contain shells of a large *Ostrea.* Formations closely comparable to this series occur at Jackson's Bay, as noted by Hector (1863), Cox (1874), and Park (1887). Cox noted the presence of foraminifera in the sandy beds and the limestones, and emphasised the similarity between the gritty beds and those associated with the coal seams at Preservation Inlet. According to the observations of Cox (1878) and the writer, closely analogous basal conglomerates overlain by thick arkosic sandstones occur in the Te Anau depression, and are exposed also in the Eglinton Valley. They are followed by grey mudstones. Such formations may thus be taken as characteristic of the Tertiary sediments which accumulated around the granite-schist-greywacke complex which is the core of Fiordland. The conditions under which such sediments were laid down would seem to have required the rapid erosion of a region originally of considerable relief, at first without the opportunity for much chemical decomposition. Eastward of Gates Harbour, McKay (1896) recognised the base of the Tertiary beds brecciated granitic material and coarse granitic boulders which had " gravitated down a steep slope." Elsewhere the basal beds seem to have been built out as confluent delta-fans with beds of peat forming in interspersed, often brackish lagoons, the angularity and large size of the boulders indicating that the parent streams were short and swift, draining from highlands near at hand, so that accumulation was probably effected rapidly in temporary flushes. When consideration is given to the fact that the area of the adjacent subsiding land mass was being reduced whilst its relief faded, there is reason to believe that the considerable thickness of the finer beds of the Tertiary sequence indicates reduction in rate of subsidence, which might permit longer retention of detritus in the shore zone, and thus facilitate its more complete trituration. This factor would combine with decrease in relief and in stream gradient to allow the accumulation of thick deposits of mudstone and marl following on the bottomset beds of the early stages of deltaic growth.

The high relief of the Fiordland area in early Tertiary times deducible from the nature of the basal members of the Tertiary beds around it, affords an exception to the general low relief inferred by Cotton (1916) for whatever lands were in existence in the New Zealand region at that period.

The Structure and Dislocation of the Tertiary Beds.

Throughout the region described these beds have been thrown into series of undulations apparently referable to two main groups; first, folding along axes running approximately north-west-south-east, and, secondly, on axes almost perpendicular thereto. McKay's (1896) section from Bald Peaks to the mouth of Wilson's River illustrates the fullest development of the first, showing a syncline followed to the south by an anticline near the present coast. The chief synclinal axis seems, however, to run from near Puysegur Point through Chalky Island. These flexures are probably but major corrugations on a general south-westward or seaward slope. Crossing these are the corrugations of the second group, which broadly may be considered as a vast transverse undulation of the abovementioned seaward slope. Its major synclines run through Chalky Island, which has thus a basin structure, and through Coal Island, the south-western coast of which has been cut back so far that its structure is rather that of a gently-warped pitching syncline than of a basin.

Between these lies the Gulches Head Peninsula, the structure of which is complex and not yet fully known. There is apparently a general south-westerly dip in the northern part of the peninsula, the southerly inclination of which was observed from Chalky Inlet. Residual patches of arkosic sediment rest on the surface of the granite to the east of Gulches Head itself and dip south-east, whilst a group of stacks lying off the south-eastern portion of this head are made up of similar sediments dipping southwards. Taken all together, these beds appear to be on the eastern limb of a southward plunging anticline, of which Gulches Head is the granitic core. This eastern limb is, however, cut by a distributed fault, with the result that the patch of arkose resting on the granite is thrown down eastward by a few closely-spaced faults with a displacement of ten or twenty feet, beyond which the major displacement brings down to sea-level adjacent to the granite a series of carbonaceous mudstones, which lie probably several hundred feet above the base of the Tertiary rocks. The continuation of Gulches Fault northward has not been mapped, but it probably passes through the small bay east of Red Head. The features do not accord with the conception of Gulches Head as merely a pre-Tertiary prominence overlapped by Tertiary sediments.

The eastern headland of Gulches Peninsula has obviously the structure of a southward-pitching anticline, and consists entirely of arkosic grits and conglomerates. Price's Beach lies in a gentle syncline, and is separated by an anticline and another syncline from the assumed prolongation of Southport Fault by the western shore of Seek Bay, all the folds apparently pitching southwards. Apart from such minor undulations, the broad structural plan shows a major corrugation in a north-east-south-west direction, making a broad syncline between Cape Providence and Gulches Head, and another between Gulches Head and Puysegur Point, the head itself being a faulted anticline. These synclines thus occupy the two major indentations of the coast. The development of a series of joints trending to the north-east parallel to one of the dominant series of joints in the basement rocks seems also to have occurred.

The strong warping of the Tertiary sediments here observed is exhibited also by the otherwise analogous sediments of Jackson's Bay (Cox, 1874).

The relation between the coastal dislocation, the jointing, and the evolution of the modern topography calls for detailed discussion, which is reserved for the next part of this report.

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List of Illustrations—Part I.

Plate 41.—Block Diagram illustrating the topography of the region about Preservation and Chalky Inlet, drawn approximately to natural scale. Based on official maps supplemented by many photographs and sketches.

PLATE 42A.—Lower Ordovician (Lancefieldian) sediments a mile and a-half north-west of Cape Providence, showing their gentle inclination. Topographic evidence of recent slight uplift and raised beach. Bartrum photo.

B.—Crumpled calc-silicate schist of the Long Sound Series on the north shore a mile from the head of Long Sound. Bartrum photo.

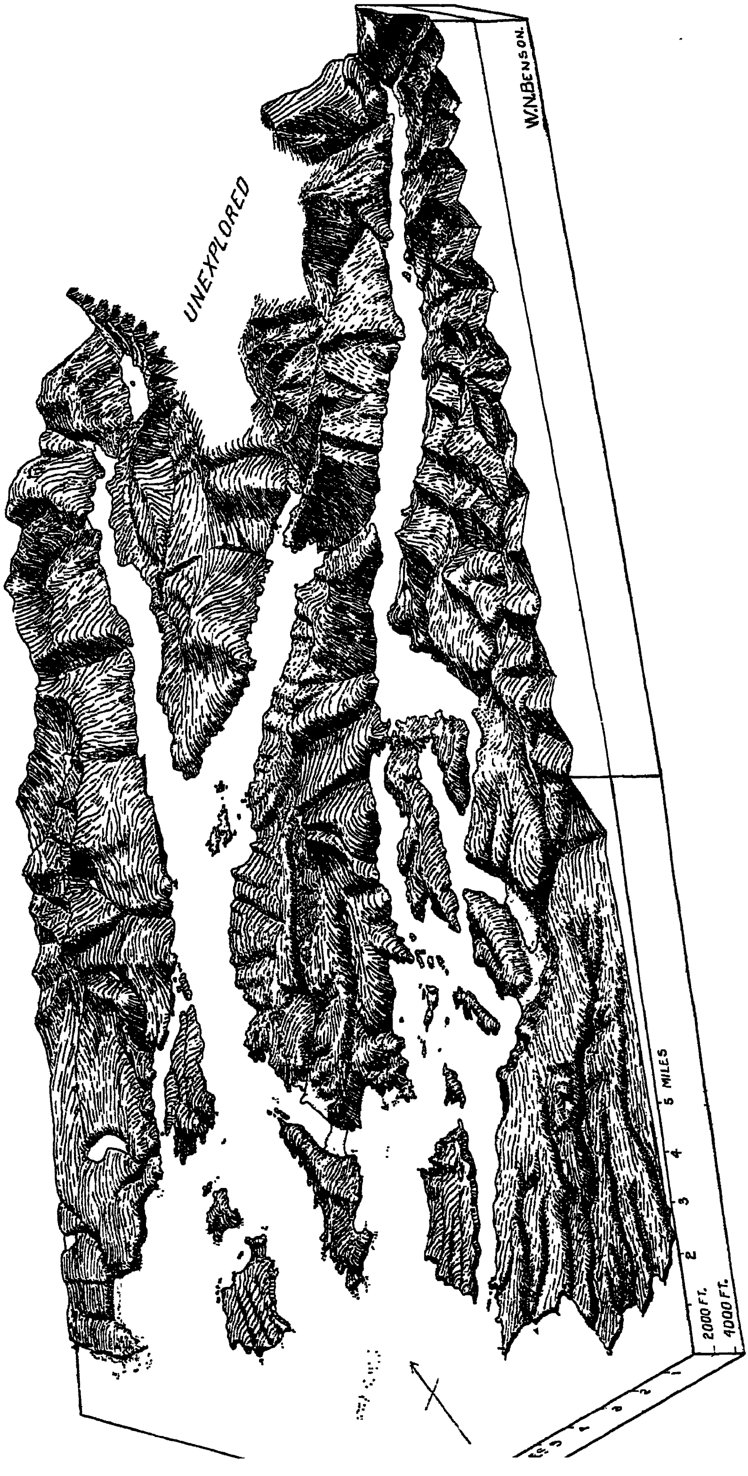
PLATE 43.—Geological Map of the region about Preservation and Chalky Inlets, together with section drawn to natural scale.

NOTE.—No definite soundings have yet been made near the axis of Long Sound. The recorded figures indicate that the depths are greater than 55 fathoms. In Cunaris Sound for Roche moutonée read Roche moutonnée.

TEXT FIGURE 1.—Lit-par-lit injection of granodiorite into the calc-silicate schists of the Long Sound Series. Observed on the north shore of Long Sound opposite Only Island. Left side S.W., right side N.E.

TEXT FIGURE 2.—General map of the south-western portion of Fiordland, illustrating the dominating directions expressed therein, the probable extent of the Coastal Plateau, and the position of the profiles traced in a plate accompanying Part II of this work.

TEXT FIGURE 3.—Section across the Last Cove Fault exposed on the north shore of Long Sound.



Block diagram of Preservation and Chalky Inlets, S.W. Fiordland, N.Z.

A.—Lower Ordovician sediments, Cape Providence.

B.—Crumpled calc-silicate schists, Long Sound.

New Zealand Astronomical Society.

REPORT OF THE SECTION FOR THE OBSERVATION OF METEORS FOR THE YEARS 1929-1931.

[*Received by Editor, 5th August, 1932; issued separately January, 1934*]

The first report of the Meteor Section of the New Zealand Astronomical Society, covering the years 1927-28, was published in 1929 (*Trans. N.Z. Inst.*, 60, p. 448, reprinted as Bulletin 5 of the N.Z. Astronomical Society). The present report, covering the work done in the past three years, is on similar lines to the preceding one.

It is a matter for satisfaction that this report has more than maintained the standard set in its predecessor. This advance is noticeable not only in membership, but also in the quantity and quality of the work performed.

A very satisfactory standard of accuracy has been maintained in the observations made. All of these have been examined and reduced by the Director, thereby ensuring uniformity in results. At the same time, it has been a special aim to train observers to perform their own reductions, with the twofold purpose of making their interest in the subject more permanent and of relieving the Director of a quantity of routine work which threatens to become unmanageable, in order that more time may be devoted to special studies which have been somewhat neglected in the past.

The observation and study of meteors in the northern hemisphere provides an opportunity for original research which is regarded as valuable. Such research is of even greater utility in this hemisphere, where we are working in a practically virgin field. It is only in recent years that the southern skies have been systematically studied by meteor observers, and the first fruits of this work are only now becoming apparent.

Despite the labours of the various observers the amount of our knowledge of the radiants, rates, and other points in connection with southern meteor showers remains surprisingly small, and the need for keen and energetic observers is as great as when the Meteor Section was initiated.

The study of meteors is an astronomical research which is eminently suited to the amateur. Nothing more than star maps and enthusiasm are required. Proficiency in observing is obtained almost at the outset, and after a little practice an observer is able to understand and interpret his observations unaided, and thereby to gain a lasting interest in his study. The possibility of original discoveries is enormous. Not only are there countless problems in meteoric astronomy requiring elucidation, but with his intimate knowledge of the starry sky there is always the chance that a meteor worker will be the first to recognise a new star or bright comet.

PERSONNEL.

Messrs Bateson and Thomsen, original members of the section, through pressure of other astronomical work, have been unable to maintain their output of meteor observations, but the acquisition of two new and active members in Messrs Geddes (February, 1931) and Butterton (October, 1931), together with valued observations and assistance from other members of the New Zealand Astronomical Society, has kept the section in a state of vigorous activity.

The following persons have contributed to the present report:—

F. M. Bateson, Wellington (B.).
M. S. Butterton, Wellington (Bu.).
M. Geddes, Otekura and New Plymouth (G.).
R. A. McIntosh, Auckland (M.).
F. J. Morshead, New Plymouth (Mo.).
I. L. Thomsen, Wellington (T.).

Occasional assistance has also been rendered by Mrs F. M. Bateson (counts of meteor rates) and C. G. Crust (reports of meteors seen).

The observations made by the members of the section are summarised in the following table:—

Obs.	1929.		1930.		1931.		Total.		Telesc. Meteors.
	h. m.	Mets.	h. m.	Mets.	h. m.	Mets.	h. m.	Mets.	
B.	10 39	106	— —	—	3 40	50	14 19	156	—
Bu.	— —	—	— —	—	3 30	15	3 30	15	—
G.	— —	—	— —	—	130 38	1500	130 38	1500	—
M.	99 48	1500	27 49	680	17 23	236	145 0	2316	—
Mo.	— —	—	— —	—	1 12	8	1 12	8	12
T.	— —	—	1 5	7	— —	—	1 5	7	1
Total	110 27	1606	28 54	687	156 23	1809	295 44	4013	13

From the above table it will be seen that an average of 13 meteors an hour has been observed under all kinds of observing conditions.

SPECIAL METEORIC SHOWERS.

The New Zealand meteor observers are greatly handicapped by not having prior knowledge of any but the most prominent meteoric displays of the year. Each night's observations bring to light entirely new radiants, and in most instances not even an approximate idea of the rate of meteoric activity to be expected is known beforehand.

Several years ago the Director compiled a catalogue from various lists of radiants, expecting that with the aid of this the radiants visible on any night could be determined before commencing observing, but the catalogue has failed in its object. In practice it has been found that only one or two out of perhaps a dozen radiants expected on any given night were actually active. Owing to the catalogue being arranged in order of date, it is also unsuitable for reference purposes.

A new catalogue, upon quite different lines, is now being prepared by the Director. In this, care is being taken to include only radiants which reasonably satisfy the modern conception of a radiant (see definition of a radiant on page 453). When completed and published it is hoped that observers in this hemisphere will possess a satisfactory calendar of meteoric activity throughout the year to guide them in their future observations.

With such a calendar, observers will then be able to plan their observations so as to fill the gaps in our present knowledge of southern meteor showers, determining dates of commencement and ending, and the maxima of the various displays, instead of scanning the sky for unknown radiants as at present.

Owing to the delay inevitably entailed in preparing and publishing such a calendar, it has been thought desirable to include in this report a summary of the most prominent showers, so far as is revealed by the work of the Meteor Section in the past three years. It is hoped that this list will be of immediate benefit to observers.

The following 36 showers appear most prominent in the data at present available:—

Corona Australids.—Mean centre of radiation, 272°, —40°; observed on March 9, 13, 20, and 26; radiants numbered 228, 232, 238, 243. There is possibly some connection between this shower and Comet 1877i, whose theoretical radiant-point is 273°, —40°, on March 15 (Herschel) or 283.3°, —38.3°, on March 28 (Davidson).

Nu Ophiuchids.—270°, —10°; 8 radiants from April 13 to 29; nos. 262, 264, 275, 280, 284, 291, 306, 314. A feeble shower.

Sagittarids.—303°, —30½°; April 13-21; nos. 272, 282, 286, 295, 304. A moderate shower.

Chi Librids.—234°, —20°; April 13-21; nos. 251, 259, 260, 263, 274, 278, 283, 289, 297, 300. A fairly prominent shower. If radiant no. 251 also belongs to this shower its duration is doubled, activity commencing on April 4. The Eta Librids in Denning's General Catalogue (Group 178, nos. 1 and 2) are identical with this series.

Delta Sagittarids.—276½°, —33°; April 14-22; nos. 270, 271, 276, 292, 302, 308. A moderate shower, already recorded by Denning (Group 210, 2 and 3). Other showers from this region are visible in May and June.

Aquilids.—289°, +7½°; April 16-21; nos. 285, 293, 303. This shower was noted by Denning as the Theta Serpentids (220, 1 and 2). It is probably connected with Comet 1844ii, whose theoretical radiant-point on April 21 is 288½°, +5°.

Lyrids.—272½°, +33°; April 21-22; nos. 301, 307. Bad weather at the epoch of this well-known northern shower (Denning, 209) has permitted observations on only two nights in the period under review. Given fine weather, satisfactory radiants could be obtained in this country, in spite of the northern declination of the radiant-point.

Eta Aquarids.—336½°, —1½° at maximum; April 28 to May 13; nos. 312, 316, 319, 321, 329, 334, 337, 338, 344, 351, 358, 363, 369, 374, 381, 382. This shower is the richest visible annually to the southern observer, and would probably rank higher in the northern hemisphere if it were not so unfavourably placed for observation there (Denning's group 258). Many rich displays have been witnessed in this country, and the radiants deduced show the unmistakable motion of the radiant-point first noted by Dr Olivier and R. M. Dole (*Observatory,* 44, 242, 1921). The Director's 1929 observations have already formed the subject of a paper (*Mon. Not., R.A.S.,* 90, 157) in which the motion of the radiant-point and the connection of the shower with Halley's comet have been dealt with. The radiants since obtained lend additional weight to the conclusions then reached.

Delta Capricornids.—324½°, —17°; April 29-May 7; nos. 315, 323, 326, 332, 342, 349. A moderate shower. The theoretical radiant-point of Comet 837i lies 10° preceding this radiant.

Lambda Sagittarids I.—273°, —29½; May 2-11; nos. 317, 320, 324, 331, 335, 339, 346, 364, 372, 377. A prominent southern shower, already noted in Denning's catalogue (210, 3 and 4).

Iota Piscis Australids.—326°, —35°; May 4-8; nos. 328, 333, 336, 341, 368. A new, moderate shower.

Beta Delphinids.—307°, +15½°; May 6-11; nos. 340, 348, 356, 359, 366, 380. This shower appears in the General Catalogue under the title Gamma Delphinids (243, 1). The radiants lie close to the theoretical radiant-point of Comet 1853ii, 296½°, +13½°, on May 1.

Beta Capricornids.—302½°, —15°; May 7-11; nos. 355, 365, 379. A fairly rich shower, not yet properly observed. It corresponds with D. 237, no. 2.

Alpha Aquarids.—327½°, —2½°; May 4-8; nos. 327, 343, 350, 360. A group of radiants lying close to the Eta Aquarids, but distinct.

Alpha Indids.—309°, —49°; May 7-8; nos. 357, 367, 370. Another small and insufficiently-observed shower.

Lambda Sagittarids II.—276½°, —25½°; June 14-19; nos. 391, 394, 398, 401. The third distinct shower from this region, the three being combined in Group 210 of Denning's catalogue (210, 4 and 5).

Beta Piscis Australids.—334°, —31°; July 2-4; nos. 406, 411, 415. This shower corresponds with Denning's group 262 (no. 2).

Psi 1 Aquarids.—349°, —9°; July 2-8; nos. 407, 412, 416, 419, 421. A shower moderately active.

Capricornid Radiants.—There are two distinct centres of radiation here in July and another in early August, all three being combined in Denning's group 237.

Capricornids I.—307°, —9°; July 5-28; nos. 418, 432, 440, 452.

Capricornids II.—302°, —17°; July 10-16; nos. 423, 435, 438.

Tau 3 Eridanids.—49°, —21°; July 31-August 8; nos. 465, 492, 511, 531. This shower has been very incompletely observed. It coincides with Denning's group 34, no. 1.

Beta Cetids.—3°, −21°; July 28-August 4; nos. 450, 456, 463, 478, 485, 488, 506. A fairly prominent shower (D. 4, 3) visible at the time of the Delta Aquarids' activity.

Iota Piscids.—351°, +4°; July 31-August 1; nos. 462, 477, 484. A small shower (D. 273, 3).

Delta Aquarids.—341°, −17° at maximum; July 26-August 9; nos. 443, 444, 445, 447, 453, 455, 460, 468, 470, 476, 483, 486, 501, 503, 515, 520, 523, 529, 535, 541. The radiants secured by the New Zealand observers have provided practically all we know of this prominent southern shower (D. 263). The long duration of the shower and the definite shift in its radiant-point, previously disputed but essential to theory, are well shown in the list of radiants secured. A note on this shower has been published by the Director in *Observatory,* 53, 675, 235. The region, especially at the beginning of August, abounds in radiants, and, being near the zenith, the short, darting meteors are difficult to observe.

Alpha Piscis Australids.—342°, −33° on July 31; July 26-August 9; nos. 442, 448, 454, 459, 467, 475, 482, 500, 502, 514, 534, 539. This well-known shower (D. 262) rivalled the Aquarids in 1929 and 1930, but was surprisingly weak in 1931. The various radiants show some evidence of movement, from R.A. 337° on July 26 to 350° on August 8.

Alpha Capricornids.—304°, −10½°; August 3-4; nos. 495, 512, 516. This shower has not often been observed. It is always low in the sky during the writer's observing hours, and has been neglected for the more favourably placed Aquarids and contemporary showers. It corresponds with Denning's group 237, nos. 17, 20, 21, and 22. The stream providing these meteors is undoubtedly connected with Comet 1881v (see orbits published in *Observatory,* 53, p. 235). Since the parent comet should return in 1933, we may look forward to good displays of meteors from this region in the next few years.

Iota Capricornids.—323°, −15½°; August 3-4; nos. 496, 504, 518, 526. Another Capricornid shower, active at the same time as the comet shower. (D. 249, nos. 12, 13, 18, 19.)

Beta Aquarids.—321°, −7°; August 4-8; nos. 505, 517, 522, 533. This shower (D. 249, 14) lies close to the prominent Delta Aquarids.

Zeta Aquarids.—336°, −0½°; August 4-9; nos. 513, 527, 538. Although not often observed locally, this seems a prominent shower, judging from the number of references to it in northern catalogues: D. 260, nos. 3, 4, 6, 7; A.M.S. 200, 1160, 1161, 1165, 1495, 1500, 1512.

Sigma Aquarids.—334°, −13°; August 5-13; nos. 519, 546, 550. A small shower helping to add confusion to the Aquarid region, as does the next.

d 1 Aquarids.—351°, −21½°; August 7-13; nos. 528, 540, 547, 554. Another small Aquarid radiant, identical with D. 252, 12.

Alpha Canis Majorids.—97°, —17°; October 16-22; nos. 580, 581, 583. This shower, apparently prominent in mid-October, has not been sufficiently observed. It corresponds with Denning's group 78 (no. 3).

Orionids.—91°, +15° at maximum; October 22; no. 576. Bad weather and moonlight have prevented satisfactory observations of this prominent northern shower (D. 77) in recent years. A series of earlier radiants has been published by the Director *(Mon. Not., R.A.S.*, 90, p. 160).

Leonids.—151°, +21½°; November 18; no. 585. The Leonid radiant (D. 115) does not rise much before dawn in this country, and therefore cannot be satisfactorily observed. The shower apparently reached its maximum in 1931 on November 18, confirming the northern hemisphere observations. It is to be hoped that a rich shower will eventuate this year, as New Zealand is in the right longitude, if not the right latitude, to see the best of the display.

Geminids.—101½°, +28°; December 3-13; nos. 593, 602. Only two radiants for this prominent shower have been secured (D. 88).

Sigma Puppids.—114°, —45°; December 4-12; nos. 591, 597, 601. This shower seems fairly prominent.

METEOR RATES IN SOUTHERN HEMISPHERE.

In the first report it was shown with the scanty data then available that the maximum of meteoric activity in this hemisphere occurred in the winter months, when the meteoric apex was highest in the sky. A full discussion of meteor rates is outside the scope of the present report, but it is hoped to publish shortly a paper dealing fully with this subject. The bare results, deduced from the corrected rates shown in Table II, confirm the earlier belief in the great frequency of meteors in the winter months.

The following table shows the rates (corrected for hindrances to observing) divided into ten-day groups, with additional columns giving the mean rate for each month, together with the number of observations on which each monthly rate is based.

Month.	Date.			Whole Month.	No. of Observations.
	1-10.	11-20.	21-31.		
January -	4	14	10	10	9
February -	7	7	8	7	18
March - -	11	8	9	9	22
April - -	14	13	14	14	30
May - -	22	12	14	16	38
June - -	13	12	12	13	22
July - -	15	15	22	17	33
August -	20	14	10	17	33
September -	11	9	12	10	11
October -	11	12	13	12	17
November -	—	11	—	11	4
December -	14	13	9	12	12

The presence of the Eta Aquarids (May 1-10) and the Delta Aquarids (July 21-August 10) is clearly shown in the above table.

Further long-continued observations are required for the purpose of determining still more accurately the rate of meteoric activity from day to day.

Cometary Accordances.

Some radiants have been observed which lie close to the theoretical radiant-points of comets which closely approach the earth's orbit, as calculated by A. S. Herschel *(Mon. Not., R.A.S.,* 38, 379) and Dr M. Davidson *(Mon. Not., R.A.S.,* 80, 739).

It is difficult at this stage to determine which of these radiants, if any, are physically connected with the cometary streams. In some cases the comet concerned is an ancient one, perhaps with an orbit not excellently determined. Even in the case of a good orbit, if the comet concerned has not been seen in recent years it may have undergone considerable perturbations in the intervening centuries, so that its apparent radiant-point no longer agrees with that calculated. Even for the rich shower from Halley's comet, the best orbits for the meteor stream are not exactly the same as the orbit of the parent comet *(Astr. Nachr.,* 196, 309, 1913, and *Mon. Not.,* 90, 157).

Another factor tending to depreciate the value of the accordances is that most of the radiants cited are isolated instances, not well-defined showers. This may be due to lack of observations at the critical time, to pronounced tenuity of the stream of meteoroids, or to chance intersections near the theoretical radiant-points of comets being misinterpreted as radiants. With further knowledge of the radiants concerned, which will result from continued observations, we can expect that in a few years these cases of possible identity will be established or ruled out.

In the following table the agreements have been divided into two classes, good and fair. In the former, physical connection seems likely; in the latter the disagreement is too great for satisfaction. Other possible cases, where the agreement is even worse, are noted only in the list of radiants (Table II).

Cometary Accordances.

I.—*Good Agreements.*

No.	Date.	Radiant.		Remarks.
		°	°	
	Mar. 25	182.5	—28.0	Comet 1264.
9	1926—Mar. 18	175.0	—20.5	
239	1931—Mar. 21	176.0	—24.0	
240	1931—Mar. 26	180.0	—24.0	
	Apl. 21	288.5	+ 5.0	Comet 1844ii.
285	1929—Apl. 16	288.0	+ 7.7	
293	1929—Apl. 17	290.0	+ 7.0	
303	1929—Apl. 21	289.3	+ 2.5	
	Apl. 20	270.5	+32.0	Comet 1861i.
301	1929—Apl. 21	272.2	+32.7	Lyrids.
307	1931—Apl. 22	272.5	+33.0	„
	May 4	337.0	0.0	Comet 1910ii.

I.—*Good Agreements*—Continued.

No.	Date.	Radiant.		Remarks.
		°	°	
329	1930—May 4	336.5	— 1.5	Eta Aquarids. See Table II for 15 other radiants.
	Aug. 4	303.2	— 9.7	Comet 1881v.
495	1929—Aug. 3	303.5	—10.5	Alpha Capricornids.
512	1929—Aug. 4	304.0	—10.5	„ „
516	1931—Aug. 2-4	304.0	—11.0	„ „
	Sept. 10	53.0	—16.0	Comet 1854iv.
87	1928—Sept. 18	60.0	—17.5	
	Oct. 16	61.0	— 7.0	Comet 1580.
578	1931—Oct. 16	59.0	— 8.5	
	Nov. 13	150.5	+23.5	Comet 1866i.
585	1931—Nov. 18	150.7	+21.4	

II.—*Fair Agreements.*

No.	Date.	Radiant.		Remarks.
		°	°	
	Jan. 20	128.5	—28.5	Comet 1840i.
206	1927—Jan. 10	113.7	—30.0	
	Mar. 15	273.0	—40.0	Comet 1877i.
228	1929—Mar. 9	272.0	—40.0	
232	1929—Mar. 13	272.0	—40.0	
238	1929—Mar. 20	272.0	—40.5	
243	1931—Mar. 26	276.0	—44.0	Comet 1590, March 8, at 275°, —38°.
	May 1	334.5	—16.0	Comet 837i.
315	1930—Apl. 29	321.0	—19.0	
323	1929—May 2	326.0	—17.5	
326	1930—May 4	322.0	—16.0	
332	1929—May 5	326.0	—17.5	
342	1930—May 6	326.0	—16.5	
349	1930—May 7	324.5	—15.0	
	May 1	296.5	+13.5	Comet 1853ii.
348	1930—May 7	308.0	+15.0	Also 4 other radiants.
380	1929—May 11	307.7	+14.0	
	Aug. 9	32.0	—18.5	Comet 1877ii.
537	1931—Aug. 9	29.0	—20.0	
	Aug. 10	40.5	—13.5	Comet 1852ii.
491	1929—Aug. 3	39.5	—15.5	
509	1929—Aug. 4	39.0	—16.0	
	Aug. 26	65.0	—22.0	Comet 1558.
174	1925—Aug. 18	55.2	—28.0	In first report.
	Sept. 20	44.5	—24.0	Comet 1763.
86	1928—Sept. 18	36.3	—28.8	In first report.
180	1928—Sept. 22	41.0	—32.0	„ „ „
	Sept. 20	62.0	—13.0	Comet 961.
181	1928—Sept. 22	60.0	—20.0	In first report.

TABLE I.

Details of Observations.

Date. 1929.		Began. h. m.	Ended. h. m.	Tl. m.	Meteors.	Horary Rate.	Factor.	Corrected Rate.	Ob.	Remarks.
Jan.	16	02 10	03 20	70	21	14	1.0	14	M	Clear.
	17	02 10	03 34	84	18	12	1.0	12	M	Clear.
	20	01 55	02 40	45	8	10	0.7	—	M	Partly cloudy.
	21	01 50	03 13	83	10	7	1.0	7	B	Clear.
	21	02 11	03 40	85	17	13	0.7	18	M	Partly cloudy.
Feb.	11	02 11	04 10	119	20	10	1.0	10	M	Clear.
	14	02 12	04 18	126	22	10	0.8	12	M	Clear; clouds ½hr.
Mar.	9	02 12	03 30	78	12	9	1.0	9	M	Clear.
	11	02 15	03 35	80	14	12	1.0	12	M	Slight mist.
	14	02 35	04 35	120	15	7	1.0	7	M	Clear.
	20	03 08	04 45	97	17	10	1.0	10	M	Clear.
Apl.	5	02 30	04 00	90	13	9	0.7	13	M	Clear; moon 25d.
	6	01 15	02 00	45	4	5	1.0	—	B	Clear.
	6	02 30	04 45	135	26	11	0.9	13	M	Clear; moon 26d.
	7	01 00	02 20	57	13	13	0.6	22	M	Misty; 23m. clouded.
	14	03 36	05 05	83	16	12	0.7	17	M	Misty; passing clouds.
	16	02 30	05 08	158	40	16	1.0	16	M	Slight mist ½hr.
	17	02 45	05 10	130	30	14	0.9	16	M	Passing clouds.
	18	02 40	05 00	140	29	12	1.0	12	M	Clear.
	22	02 45	05 23	158	37	13	0.6	22	M	Clear; moon 12d.
May	3	03 00	05 30	150	36	14	0.5	28	M	Clear; moon 22d.
	4	02 40	04 00	55	8	—	—	—	M	Clouds 45m.; moon 23d.
	6	02 30	05 30	180	52	17	0.8	21	M	Some cloud; moon 25d.
	7	02 30	03 40	70	13	11	0.6	18	M	Misty; much cloud.
	8	02 30	05 30	155	57	22	1.0	22	M	Misty; 25m. off.
	9	02 37	05 40	148	46	18	0.9	20	M	35m. clouded.
	10	02 50	03 05	—	6	—	—	—	M	Casuals.
	11	02 20	03 40	60	12	12	0.6	20	M	Clouds 20m.; misty.
	12	00 25	05 40	315	80	15	1.0	15	M	Clear.
	13	02 25	02 50	—	5	—	—	—	M	Almost wholly clouded.
June	1-2	11 52	01 10	78	14	10	0.9	11	M	Clear; moon.
	2	00 10	02 00	110	17	9	0.9	10	B	Some light clouds.
	8	01 45	02 20	35	5	8	1.0	—	B	Clear.
	9	01 10	03 30	140	27	11	1.0	11	M	Clear.
July	3	02 48	05 08	140	29	12	0.8	14	M	Clear; moon 23d.
	4	02 45	04 45	120	25	12	1.0	12	M	Clear.
	5	02 45	05 30	165	36	13	1.0	13	M	Clear.
	6	02 30	04 30	105	26	15	0.9	16	M	Fog; 15m. off.
	9	02 45	04 00	50	19	23	1.0	—	M	Rain storms; 25m. off.
	11	03 05	04 50	105	35	19	0.9	21	M	Clear.
	27	02 45	04 30	105	17	10	0.3	—	M	Clear; moon 19d.
	29	02 40	04 10	57	22	19	0.5	38	M	Clouds 23m.; moon 21d.
	31	02 22	03 48	86	23	23	0.8	30	M	Clouds 48m.; moon 23d.
Aug.	1	03 30	05 30	120	51	23	0.8	30	M	Some clouds; moon 24d.
	1-2	20 25	22 08	130						
		22 20	00 06	106	30	8	1.0	8	B	Clear.
	2	02 30	05 30	180	67	22	0.9	25	M	Clear; moon 25d.
	4	01 10	05 30	260	103	23	1.0	23	M	Clear.
	4-5	23 45	01 02	77	19	15	1.0	15	B	Clear.
	5	02 25	04 20	110	54	27	1.0	27	M	Clear.
	9	02 30	04 30	120	41	20	1.0	20	M	Slight mist.
	9-10	23 40	01 00	80	19	14	0.9	15	B	Some clouds.
	13	02 44	04 45	121	41	18	0.9	20	M	Slight mist.
	14	02 44	04 15	91	24	15	0.8	19	M	Passing clouds.

TABLE 1.—DETAILS OF OBSERVATIONS—Continued.

Date.	Began.	Ended.	Tl.	Meteors.	Horary Rate.	Factor.	Corrected Rate.	Ob.	Remarks.
1929.	h. m.	h. m.	m.						
Sept. 1	00 45	01 40	55	10	11	1.0	11	M	Clear.
2	02 54	04 20	86	15	10	1.0	10	M	Clear.
12	02 42	03 55	73	16	13	1.0	13	M	Clear.
30	02 25	04 15	110	18	10	1.0	10	M	Slight mist.
Oct. 5	02 30	03 05	35	3	7	1.0	—	M	Slight mist.
6	01 05	03 20	135	21	9	1.0	9	M	Clear.
7	02 30	04 05	95	17	11	1.0	11	M	Slight mist.
16	02 30	04 05	83	7	—	—	—	M	Clear; moon 13d.
17	03 05	03 45	40	2	—	—	—	M	Clear; moon 14d.
18	02 50	03 20	30	5	—	—	—	M	Clear; moon 15d.
19	03 05	03 25	20	3	—	—	—	M	Clear; moon 16d.
29	02 50	03 35	45	13	15	1.0	—	M	Clear.
Dec. 13	02 25	03 05	40	8	9	1.0	—	M	Clear.
1930.									
Apl. 30	03 00	05 00	120	27	13	1.0	13	M	Clear.
May 3	02 56	05 20	144	37	15	0.9	17	M	Slight mist.
5	02 45	05 25	160	72	27	1.0	27	M	Clear.
6	02 45	05 25	160	65	24	1.0	24	M	Clear.
7	02 30	05 30	180	84	28	1.0	28	M	Clear.
8	02 30	05 30	165	63	23	0.9	25	M	Passing clouds.
9	02 40	04 25	105	39	22	1.0	22	M	Clear.
July 29	20 42	21 47	65	6	6	0.8	7	T	Clear.
29	03 26	05 10	104	45	26	0.8	33	M	Misty; some clouds.
30	02 45	04 50	125	52	25	1.0	25	M	Clear.
31	03 05	04 45	100	39	23	1.0	23	M	Clear.
Aug. 1	03 15	05 16	121	66	33	1.0	33	M	Clear.
2	02 50	05 00	120	63	32	1.0	32	M	Clear; 10m. off.
Sept. 23	03 05	04 10	65	18	16	1.0	16	M	Clear.
1931.									
Feb. 3	20 16	21 16	60	1	1	—	—	G	Clear; moon 15d.
5	20 26	21 37	71	3	3	—	—	G	Clear; moon 17d.
8	19 57	22 02	125	13	6	1.0	6	G	Clear.
9	20 18	22 13	115	9	4	0.8	7	G	Smoke.
11	20 28	21 23	55	6	6	1.0	6	G	Clear.
14	19 54	21 36	102	4	2	1.0	2	G	Clear.
15	20 28	22 34	126	15	7	0.9	8	G	Light clouds.
16	20 47	21 59	72	6	5	1.0	5	G	Clear.
18	20 13	22 36	143	19	8	1.0	8	G	Clear.
26	20 05	21 05	60	3	3	0.6	5	G	Haze; moon 9d.
Mar. 12	20 05	20 12	7	1	—	—	—	G	
13	20 10	22 24	134	15	7	1.0	7	G	Clear.
14	21 08	22 10	62	7	7	1.0	7	G	Clear.
20	20 00	23 43	223	37	10	1.0	10	G	Clear.
21	03 05	03 47	42	9	13	1.0	—	M	Mist on horizon.
22	00 30	01 15	45	17	12	1.0	—	M	Clear.
27	02 45	03 35	60	12	5	1.0	5	M	Clear.
27	20 13	22 10	117	5	2	0.4	6	G	Passing clouds; moon.
28-29	21 30	01 03	213	43	12	0.8	17	G	Clear; moon 9d.
30	03 00	03 18	18	7	19	0.9	—	M	Passing clouds.
Apl. 10	20 08	21 45	97	8	6	0.4	15	G	Very cloudy.
12_13	20 05	00 22	257	48	11	1.0	11	G	Clear.
13	21 05	22 00	55	3	3	0.3	10	G	90% cloud.
14	03 00	05 05	125	33	15	0.9	16	M	Clear; moon 23d.
14-15	22 05	01 12	187	43	14	1.0	14	G	Clear.
15	03 00	04 20	80	20	15	1.0	15	M	Clear.
15	20 45	23 03	138	29	12	1.0	12	G	Clear.
17	21 18	22 50	92	15	10	0.8	12	G	Passing clouds.
21-22	22 35	00 25	110	29	16	1.0	16	G	Clear.
22	21 45	23 00	75	15	12	0.9	13	G	Slight clouds.
23	03 00	05 00	120	35	17	0.9	19	M	Slight fog.
23-24	22 47	00 15	98	22	13	1.0	13	G	Clear.
29	03 00	04 40	100	18	11	0.9	12	M	Slight mist.

TABLE 1.—Details of Observations—Continued.

Date. 1931.		Began. h. m.	Ended. h. m.	Tl. m.	Meteors.	Horary Rate.	Factor.	Corrected Rate.	Ob.	Remarks.
May	13	21 43	23 15	92	18	12	0.9	13	G	Cloud and haze.
	14	02 55	03 35	40	12	18	0.9	—	M	Mist and cloud; moon.
	14	21 37	22 33	56	11	12	0.9	13	G	Cloud on horizon.
	15	20 47	22 02	75	13	10	0.9	11	G	Clear.
	22-23	22 43	00 00	77	17	13	1.0	13	G	Clear.
June	7	20 45	23 00	135	27	12	0.9	13	G	Clear.
	14	20 55	23 05	130	18	8	0.7	11	G	Much passing cloud.
	15-16	19 53	01 00	307	67	13	0.9	14	G	Slight haze at first.
	18-19	22 52	01 18	146	34	14	1.0	14	G	Clear.
	19-20	23 13	02 33	200	56	17	1.0	17	G	Clear.
July	6	21 57	23 13	76	15	12	0.7	17	G	Passing cloud.
	10-11	21 37	00 22	165	35	13	0.8	16	G	30% cloud.
	14-15	20 50	21 00							
		22 15	02 20	255	48	11	0.5	22	G	60% cloud.
	15-16	21 57	00 05	128	21	11	0.4	28	G	70% cloud.
	16	02 57	03 40	43	12	18	—	—	M	Partially cloud.
	16	20 39	22 24							
		23 12	23 58	155	28	11	0.5	22	G	50% cloud.
	17	22 45	23 30	45	7	9	0.3	—	G	70% cloud.
	20-21	20 05	01 55	330	61	11	0.7	16	G	25% cloud; moon 5d.
Aug.	2	19 30	22 00	150	16	6	0.3	20	G	50% cloud; moon.
	4-5	21 40	00 40	180	28	9	0.7	13	G	20% cloud; moon.
	5	20 15	24 00	225	64	17	1.0	17	G	Clear.
	6-7	21 43	00 02	139	52	22	1.0	22	G	Clear.
	7-8	22 33	01 00	147	58	22	1.0	22	G	Clear.
	9-10	22 30	03 30	300	86	17	0.8	21	G	20% cloud.
	10	22 05	22 35	30	6	12	0.5	—	G	Almost totally clouded.
	13-14	21 25	02 25	300	69	14	1.0	14	G	Clear.
	14-15	22 23	00 25	122	30	15	1.0	15	G	Clear.
	21	01 26	05 00	214	44	12	1.0	12	G	Clear.
Oct.	2-3	22 45	00 45	120	22	11	0.9	12	G	Much haze.
	12	02 08	02 45	37	3	6	—	—	M	Almost totally clouded.
	14	02 25	03 28	63	7	7	0.9	7	M	Some clouds.
	15-16	23 30	01 20	110	9	4	—	—	B	Almost totally clouded.
	16	02 40	03 45	65	7	7	—	—	M	Almost totally clouded.
	17	00 00	03 30	210	34	9	1.0	9	B	Clear.
	17	00 00	03 30	210	15	4	1.0	4	Bu	Clear.
	23	02 25	03 50	85	11	8	0.9	12	M	Clear; moon.
Nov.	15	01 18	02 30	72	8	7	0.5	16	Mo	50% cloud.
	15	02 28	03 15	47	3	4	1.0	—	B	Clear.
	16	02 15	03 15	60	15	11	1.0	11	M	Clear, twilight.
	16	02 00	02 30	30	0	—	—	—	G	70% cloud.
	18	01 50	03 00	70	13	11	0.9	12	G	Hazy.
Dec.	3-4	22 21	01 07	166	32	12	0.8	15	G	35% cloud.
	4-5	22 38	01 12	154	35	12	0.8	15	G	20% cloud.
	10-11	23 32	01 20	108	24	13	0.8	16	G	Hazy, twilight at end.
	14	02 00	03 00	60	7	—	—	—	M	Casual watch.
	28	21 07	22 07	60	8	8	0.9	9	G	Hazy.
	30	21 05	22 55	110	11	6	0.9	7	G	Some cloud.

TABLE 2.—LIST OF RADIANT POINTS OBSERVED—Continued.

No.	Date.	G.M.T.	Radiant. R.A.	Radiant. Dec.	Mets.	Wt.	Obs.	L.	Remarks.
			°	°				°	
261	1931—Apl.	13.69	260.5	—36.0	5	G	M	291.8	29. 279, ? 290.
262	1931—Apl.	13.69	266.0	— 9.5	2	F	M	„	Nu Oph.
263	1929—Apl.	13.70	232.5	—20.5	6	G	M	292.3	Chi Lib.
264	1929—Apl.	13.70	270.0	—10.0	4	F	M	„	Nu Oph
265	1929—Apl.	13.70	307.5	—65.0	4	G	M	„	? 281.
266	1931—Apl.	14.50	192.0	—14.0	3	G	G	292.7	255; ? D. 158, 19.
267	1931—Apl.	14.50	209.0	— 4.0	3	F	G	„	256; ? D. 158, 14.
268	1931—Apl.	14.50	215.0	—65.0	4-5	G	G	„	258.
269	1931—Apl.	14.50	233.5	—39.0	6	G	G	„	273.
270	1931—Apl.	14.50	275.5	—32.5	3	F	G	„	Delta Sgr.
271	1931—Apl.	13-14	279.0	—39.0	5-6	F	M	292.4	Delta Sgr.
272	1931—Apl.	13-14	304.5	—34.5	7-8	G	M	„	Sgr.
273	1931—Apl.	15.43	234.0	—40.0	6	G	G	293.6	269.
274	1931—Apl.	15.43	237.0	—19.5	3	P	G	„	Chi Lib.
275	1931—Apl.	15.43	270.0	—10.0	2	P	G	„	Nu Oph.
276	1931—Apl.	15.43	275.0	—30.0	2	F	G	„	Delta Sgr.
277	1929—Apl.	15.68	152.5	—67.0	3	F	M	294.2	
278	1929—Apl.	15.68	233.5	—20.0	3	G	M	„	Chi Lib.
279	1929—Apl.	15.68	260.0	—36.0	10	G	M	„	261, 299, ? 290.
280	1929—Apl.	15.68	269.0	— 9.0	4	F	M	„	Nu Oph.
281	1929—Apl.	15.68	301.0	—68.0	2	P	M	„	? 265.
282	1929—Apl.	15.68	301.0	—31.0	5	G	M	„	Sgr.
283	1929—Apl.	16.69	238.3	—21.0	4	G	M	295.2	Chi Lib.
284	1929—Apl.	16.69	267.0	—10.0	2	P	M	„	Nu Oph.
285	1929—Apl.	16.69	288.0	+ 7.7	7	G	M	„	Aql.
286	1929—Apl.	16.69	300.0	—30.5	4	G	M	„	Sgr.
287	1929—Apl.	16.69	300.0	—53.0	3	F	M	„	? 16, ? 294.
288	1931—Apl.	17.44	226.5	—23.0	3	F	G	295.5	? 297.
289	1929—Apl.	17.68	232.5	—21.0	2	P	M	296.2	Chi Lib.
290	1929—Apl.	17.68	258.5	—42.5	6	G	M	„	? 261, ? 279.
291	1929—Apl.	17.68	269.0	—10.0	3	G	M	„	Nu Oph.
292	1929—Apl.	17.68	273.5	—28.5	5	G	M	„	Delta Sgr.
293	1929—Apl.	17.68	290.0	+ 7.0	2	P	M	„	Aql.
294	1929—Apl.	17.68	297.0	—57.5	2	P	M	„	146, ? 287.
295	1929—Apl.	17.68	300.0	—30.5	2	P	M	„	Sgr.
296	1931—Apl.	21.50	203.5	—22.4	4-5	F	G	299.5	
297	1931—Apl.	21.50	229.5	—18.7	5	G	G	„	? Chi Lib.; ? 288.
298	1931—Apl.	21.50	269.0	—45.5	4	G	G	„	
299	1931—Apl.	21.50	269.5	—37.3	4	F	G	„	261, 279, ? 290.
300	1929—Apl.	21.69	238.5	—21.7	3	F	M	300.0	Chi Lib.
301	1929—Apl.	21.69	272.2	32.7	6	G	M	„	Lyrids.
302	1929—Apl.	21.69	277.0	—34.7	7	G	M	„	Delta Sgr.
303	1929—Apl.	21.69	289.3	+ 2.5	7	G	M	„	Aql.
304	1929—Apl.	21.69	303.0	—30.0	4	G	M	„	Sgr.
305	1931—Apl.	22.69	245.0	—35.0	4-5	F	M	300.7	
306	1931—Apl.	22.69	272.0	—14.0	3	P	M	300.7	Nu Oph.
307	1931—Apl.	22.69	272.5	+33.0	4	G	M	„	Lyrids.
308	1931—Apl.	22.69	278.0	—34.0	2-3	F	M	„	Delta Sgr.
309	1931—Apl.	23.50	259.0	—67.5	3	P	G	301.5	
310	1931—Apl.	28.68	285.0	—38.0	3-4	G	M	306.5	318.
311	1931—Apl.	28.68	325.0	—28.5	3	F	M	„	
312	1931—Apl.	28.68	330.5	— 5.0	2	?	M	„	? Early Aquarids.
313	1930—Apl.	29.69	251.0	—28.7	5	G	M	307.7	
314	1930—Apl.	29.69	270.0	—10.0	4-5	F	M	„	Nu Oph.
315	1930—Apl.	29.69	321.0	—19.0	3	F	M	„	Delta Cap.
316	1930—Apl.	29.69	330.3	— 3.5	5	F	M	„	Aquarids.
317	1930—May	2.69	270.5	—27.0	2	F	M	310.6	Lambda Sgr.
318	1930—May	2.69	286.0	—37.0	3	F	M	„	D. 217, 1; NZ 310.
319	1930—May	2.69	334.0	— 2.0	19	G	M	„	Aquarids.

TABLE II.

List of Radiant Points Observed.

No.	Date.	G.M.T.	Radiant.		Mets.	Wt.	Obs.	L.	Remarks.
			R.A.	Dec.					
			°	°				°	
205	1929—Jan.	15.64	107.0	—36.0	5	F	M	204.7	
206	1929—Jan.	15.64	120.0	—29.0	6	G	M	„	Comet 1840i; NZ 1.
207	1929—Jan.	15.64	132.2	+ 7.0	4	G	M	„	
208	1929—Jan.	16.64	134.0	—57.0	7	G	M	205.7	
209	1929—Jan.	16.64	177.7	—18.6	7	G	M	„	D. 132, 1; 132, 2; ? 212.
210	1929—Jan.	19.62	162.1	—13.7	5	G	M	208.7	NZ 2.
211	1929—Jan.	20.64	132.5	—50.5	5	G	M	209.7	NZ 130, 214.
212	1929—Jan.	20.64	177.0	—11.0	5	F	M	„	? 219.
213	1929—Jan.	20.64	144.0	—42.0	4	F	M	„	
214	1929—Jan.	21.60	130.0	—54.0	3	P	B	210.7	211, 130.
215	1931—Feb.	8-9	53.0	—23.0	4-5	F	G	229.3	223.
216	1931—Feb.	8-9	89.0	—43.5	4	G	G	„	
217	1931—Feb.	8-9	94.5	—27.4	4-5	G	G	„	
218	1929—Feb.	10.65	206.5	—43.4	5	G	M	230.7	222; ? Comet 1887iii.
219	1929—Feb.	10.65	212.9	—67.0	3	G	M	„	
220	1929—Feb.	10.65	221.5	—39.1	5	G	M	„	
221	1929—Feb.	13.66	189.0	—61.0	3	F	M	233.7	
222	1929—Feb.	13.66	205.5	—42.2	6	G	M	„	218.
223	1931—Feb.	15-18	53.0	—19.3	5	F	G	237.2	215.
224	1931—Feb.	15-18	59.5	—27.0	3	P	G	„	
225	1931—Feb.	15-18	71.0	—42.0	4	F	G	„	
226	1929—Mar.	9.64	241.5	—43.0	7	F	M	257.7	
227	1929—Mar.	9.64	235.0	—19.0	4	P	M	257.7	D. 178, 2; NZ 138.
228	1929—Mar.	9.64	272.0	—40.0	4	P	M	„	CrA.
229	1931—Mar.	13.41	29.0	—26.0	1	F	G	261.0	Stationary meteor.
230	1931—Mar.	13.41	100.0	—47.5	3	F	G	„	
231	1929—Mar.	13.67	231.3	—42.0	5	G	M	261.6	? BAA 158.
232	1929—Mar.	13.67	272.0	—40.0	3	F	M	„	CrA.
233	1931—Mar.	13-14	72.0	—53.5	7	G	G	261.5	Inc. 1 statn.
234	1931—Mar.	13-14	170.0	—40.0	5	F	G	„	? 244.
235	1931—Mar.	20.43	197.0	—31.0	4	F	G	268.0	
236	1931—Mar.	20.43	219.0	—45.0	5-7	G	G	„	
237	1929—Mar.	20.68	272.0	—21.5	4	G	M	268.6	
238	1929—Mar.	20.68	272.0	—40.5	7	G	M	„	CrA.
239	1931—Mar.	21.66	176.0	—24.0	4	F	M	269.1	9, 240, AMS 888; Comet 1556.
240	1931—Mar.	26.66	180.0	—24.0	2	F	M	274.1	9, 239; Comet 1264.
241	1931—Mar.	26.66	219.0	—11.5	5	F	M	„	? 246.
242	1931—Mar.	26.66	241.5	—27.0	5	G	M	„	? 10.
243	1931—Mar.	26.66	276.0	—44.0	5	F	M	„	CrA.
244	1931—Mar.	28.49	178.0	—41.0	4-5	F	G	276.0	? 234.
245	1931—Mar.	28.49	213.0	—45.0	3-4	G	G	„	
246	1931—Mar.	28.49	217.5	—15.5	5	G	G	„	? 241.
247	1931—Mar.	28.49	240.5	—19.5	3	F	G	„	BAA 21.
248	1931—Mar.	28.49	247.5	—39.0	3	F	G	„	
249	1929—Apl.	3-6	241.0	— 4.0	5	G	M	—	D. 187, 4; 187, 5; 178 ?
250	1929—Apl.	3-6	261.5	—32.0	7	G	M	—	
251	1929—Apl.	4-6	230.0	—21.0	8	G	M	—	Chi Lib.
252	1929—Apl.	4-6	247.5	—50.0	7	G	M	—	D. 189.
253	1929—Apl.	4-6	285.0	—53.0	7	G	M	—	? 11.
254	1929—Apl.	5-6	212.0	—13.0	6	G	M	—	D. 166, 4; 166, 8; 158, 11; AMS 924.
255	1931—Apl.	13.42	191.5	—15.5	6	G	G	291.6	266.
256	1931—Apl.	13.42	205.5	+ 0.7	5-7	G	G	„	267.
257	1931—Apl.	13.42	209.0	—27.0	5-7	F	G	„	Comet 1737i.
258	1931—Apl.	13.42	218.0	—64.5	4	G	G	„	268.
259	1931—Apl.	13.42	235.0	—18.0	5	F	G	„	Chi Lib.
260	1931—Apl.	13.09	233.5	—19.5	8	G	M	291.8	Chi Lib.

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320	1929—May	2.70	272.5	—35.0	8	G	M	310.9	Lambda Sgr.
321	1929—May	2.70	334.0	— 1.5	18	G	M	„	Aquarids.
322	1929—May	2-3	313.0	—42.0	5	G	M	„	
323	1929—May	2-3	326.0	—17.5	3	F	M	„	Delta Cap.
324	1930—May	4.69	271.0	—29.0	3	F	M	312.6	Lambda Sgr.
325	1930—May	4.69	302.3	—21.5	6	G	M	„	
326	1930—May	4.69	322.0	—16.0	3	F	M	„	Delta Cap.
327	1930—May	4.69	324.0	— 4.5	6-7	G	M	„	Inc. 1 stn. Alpha Aqr.
328	1930—May	4.69	326.0	—35.0	3	F	M	„	Iota PsA.
329	1930—May	4.69	336.5	— 1.5	36	G	M	„	Aquarids.
330	1929—May	5.69	257.0	0.0	3	F	M	313.9	D. 193, 1.
331	1929—May	5.69	272.0	—27.3	8	G	M	„	Lambda Sgr.
332	1929—May	5.69	326.0	—17.5	6	G	M	„	Delta Cap.
333	1929—May	5.69	327.4	—35.0	6	G	M	„	Iota PsA.
334	1929—May	5.69	337.5	— 1.0	19	G	M	„	Aquarids.
335	1930—May	5.69	277.0	—27.0	3	F	M	313.6	Lambda Sgr.
336	1930—May	5.69	327.0	—33.0	2-3	P	M	„	Iota PsA.
337	1930—May	5.69	337.0	— 1.0	33	G	M	„	Aquarids.
338	1929—May	6.65	338.6	0.0	5	F	M	314.9	Aquarids.
339	1929—May	6.69	272.0	—27.0	5	G	M	314.6	Lambda Sgr.
340	1930—May	6.69	305.0	17.0	3	F	M	„	Beta Del.
341	1930—May	6.69	325.5	—34.5	4.5	G	M	„	Iota PsA.
342	1930—May	6.69	326.0	—16.5	3	F	M	„	Delta Cap.
343	1930—May	6.69	327.0	— 2.5	8-9	G	M	„	Alpha Aqr.
344	1930—May	6.69	338.0	— 0.5	38	G	M	„	Aquarids.
345	1930—May	6.69	356.0	— 5.0	4	G	M	„	
346	1930—May	7.68	270.0	—30.0	3	P	M	315.6	Lambda Sgr.
347	1930—May	7.68	298.5	— 1.2	4	F	M	„	D. 230, 5.
348	1930—May	7.68	308.0	15.0	5	G	M	„	Beta Del.
349	1930—May	7.68	324.5	—15.0	3	F	M	„	Delta Cap.
350	1930—May	7.68	329.0	— 1.0	5-7	G	M	„	Alpha Aqr.
351	1930—May	7.68	339.0	0.0	28	G	M	„	Aquarids.
352	1930—May	7.68	351.0	—46.0	3	F	M	„	
353	1929—May	7.69	240.0	—15.0	4	F	M	315.9	D. 190, 3.
354	1929—May	7.69	271.0	—10.0	3	F	M	„	
355	1929—May	7.69	302.5	—12.5	7	G	M	„	Beta Cap.
356	1929—May	7.69	307.0	14.0	3	F	M	„	Beta Del.
357	1929—May	7.69	308.0	—48.0	6	G	M	„	Alpha Ind. 8; Cor
358	1929—May	7.69	339.0	— 0.4	24	G	M	„	Aquarids. 12
359	1930—May	8.67	307.5	+14.5	3	G	M	316.5	Beta Del.
360	1930—May	8.67	330.0	— 1.0	3	G	M	„	Alpha Aqr.
361	1930—May	8.67	336.5	— 0.5	3-4	G	M	„	
362	1930—May	8.67	338.0	—30.5	5	G	M	„	
363	1930—May	8.67	340.0	+ 0.5	13	G	M	316.5	Aquarids.
364	1929—May	8.69	273.0	—32.0	3	P	M	316.8	Lambda Sgr.
365	1929—May	8.69	302.5	—15.0	9	G	M	„	Beta Cap.
366	1929—May	8.69	307.5	+14.5	4	G	M	„	Beta Del.
367	1929—May	8.69	308.0	—49.0	6	G	M	„	Alpha Ind.
368	1929—May	8.69	325.0	—36.0	2	P	M	„	Iota PsA.
369	1929—May	8.69	339.0	+ 0.3	10	G	M	„	Aquarids.
370	1930—May	7-8	310.5	—49.3	5	G	M	316.0	Alpha Ind.
371	1929—May	9-10	245.0	—60.0	3	F	M	317.9	BAA 163.
372	1929—May	9-10	275.0	—32.5	3	F	M	„	Lambda Sgr.
373	1929—May	9-10	300.0	—26.0	3	F	M	„	378.
374	1931—May	11.66	339.5	+ 2.0	2	P	M	319.2	? Aquarids.
375	1929—May	11.69	237.5	+ 1.0	4	P	M	319.7	? D. 177, 9; ? D. 187, 6.
376	1929—May	11.69	242.0	—30.5	10	G	M	„	
377	1929—May	11.69	275.0	—28.0	3	P	M	„	Lambda Sgr.
378	1929—May	11.69	301.0	—24.5	8	G	M	„	373.
379	1929—May	11.69	302.0	—15.0	7	F	M	„	Beta Cap.
380	1929—May	11.69	307.7	+14.0	7	G	M	„	Beta Del.
381	1929—May	11.69	342.7	+ 2.5	21	G	M	„	Aquarids.

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382	1931—May	13.66	341.0	+ 2.0	3	P	M	321.2	? Aquarids.
383	1931—May	13-14	234.0	—54.0	4	G	G	321.6	
384	1931—May	22.49	259.0	—23.5	7	G	G	329.7	? 25, ? 32.
385	1929—June	1.54	286.5	—38.0	4	F	M	340.0	152.
386	1931—June	7.43	264.5	—42.5	8	G	G	345.3	
387	1929—June	8.62	272.0	—12.0	4	P	M	346.9	D. 204, 3; AMS 1040.
388	1929—June	8.62	277.0	—35.0	9	G	M	„	156; D. 210, 4.
389	1929—June	8.62	296.0	+ 1.0	4	F	M	„	D. 230, 7; AMS 1069.
390	1929—June	8.62	327.0	+ 0.5	3	G	M	„	D. 251, 1; D. 260, 1.
391	1931—June	14.44	275.5	—27.0	3	P	G	352.1	Lambda Sgr.
392	1931—June	15.46	254.0	—51.5	6-7	G	G	353.1	
393	1931—June	15.46	268.5	—28.0	4-5	G	G	„	D. 210, 5.
394	1931—June	15.46	276.5	—26.5	4-5	G	G	„	Lambda Sgr.
395	1931—June	15.46	285.0	—15.0	11	G	G	„	D. 218, 3; NZ 402.
396	1931—June	15.46	291.0	—27.5	4-5	F	G	„	? 40.
397	1931—June	15.46	313.5	—55.0	3-4	F	G	„	
398	1931—June	18.52	272.5	—23.0	3-4	F	G	356.0	? Lambda Sgr.
399	1931—June	18.52	292.0	— 5.0	4-6	G	G	„	
400	1931—June	18.52	292.0	—18.0	6-8	G	G	„	403.
401	1931—June	19.56	277.8	—24.5	6	G	G	357.0	Lambda Sgr.
402	1931—June	19.56	282.0	—11.5	4	F	G	„	395; D. 218, 3; AMS 1040.
403	1931—June	19.56	289.0	—18.0	3	F	G	„	400.
404	1929—July	2.69	10.0	+ 5.0	8	P	M	10.3	D. 2, 1; Comet 1864ii.
405	1929—July	2.69	310.5	—13.0	3	F	M	„	410; AMS 1098; D. 249, 1.
406	1929—July	2.69	334.0	—30.0	8	G	M	„	Beta PsA.
407	1929—July	2.69	348.5	— 9.5	5	G	M	„	Psi 1 Aqr.
408	1929—July	2.69	353.0	+25.0	5	P	M	„	D. 5, 1; ? D. 274, 1; Comet 1908c.
409	1929—July	3.68	286.0	—28.0	6	F	M	11.3	D. 221, 2; 227, 3; BAA 177.
410	1929—July	3.68	310.5	—14.0	4	F	M	„	405; AMS 1098; D. 249, 1.
411	1929—July	3.68	334.0	—31.0	5	G	M	„	Beta PsA.
412	1929—July	3.68	348.5	— 9.0	4	G	M	„	Psi 1 Aqr.
413	1929—July	2-3	326.0	—22.0	4	G	M	—	? 45.
414	1929—July	4.69	316.0	—36.0	7	F	M	12.2	425; ? D. 239, 1.
415	1929—July	4.69	334.0	—32.0	5	F	M	„	Beta PsA.
416	1929—July	4.69	348.5	— 9.0	10	G	M	„	Psi 1 Aqr.
417	1929—July	5.67	290.0	— 9.0	6	F	M	13.1	D. 226, 6.
418	1929—July	5.67	301.0	— 7.5	4	F	M	13.1	Cap. I.
419	1929—July	5.67	350.0	— 9.0	4	F	M	„	Psi 1 Aqr.
420	1929—July	6.46	287.0	—23.8	4	G	G	13.3	54; 431.
421	1929—July	8.66	348.5	— 8.0	5	G	M	16.0	Psi 1 Aqr.
422	1929—July	10.69	37.5	+ 4.7	5	F	M	17.9	D. 26, 1.
423	1929—July	10.69	302.0	—15.0	6	F	M	„	Cap. II.
424	1929—July	10.69	351.0	—41.0	5	G	M	„	449; D. 275, 1.
425	1929—July	8-10	312.0	—34.0	4	P	M	17.0	414.
426	1931—July	10-11	260.0	—60.0	4	G	G	17.7	
427	1931—July	10-11	305.0	—64.0	4	G	G	„	
428	1931—July	10-11	306.0	—30.7	5	G	G	„	
429	1931—July	10-11	323.0	—42.0	5	G	G	„	66.
430	1931—July	14.49	25.0	— 8.5	3	G	G	21.2	Inc. 1 stn. 49.
431	1931—July	14.49	291.7	—22.0	6-7	G	G	„	54, 63, 420.
432	1931—July	14.49	307.0	— 7.5	3	F	G	„	Cap. I.
433	1931—July	14.49	324.0	—52.0	4	G	G	„	
434	1931—July	14.49	309.0	—23.5	3	G	G	21.4	
435	1931—July	14-15	302.0	—17.0	6	G	G	21.7	Cap. II.
436	1931—July	14-15	344.0	—29.7	4	G	G	„	
437	1931—July	16-17	277.5	—37.0	6	G	G	23.7	? 53, A1461.
438	1931—July	16-17	300.5	—18.0	4-5	F	G	„	Cap. II.

TABLE 2.—LIST OF RADIANT POINTS OBSERVED—Continued.

No.	Date.	G.M.T.	Radiant.		Mets.	Wt.	Obs.	L.	Remarks.
			R.A.	Dec.					
			°	°				°	
439	1931—July	20.49	267.0	—30.0	5	G	G	27.0	62; Comet 568.
440	1931—July	20.49	311.0	—10.0	15	G	G	„	Cap. I.
441	1931—July	20.49	351.5	—39.0	4	G	G	„	
442	1929—July	26.67	337.0	—33.0	4	P	M	33.5	Alpha PsA.
443	1929—July	26.67	339.6	—17.0	5	G	M	„	Delta Aquarids.
444	1929—July	28.66	341.0	—16.5	8	G	M	35.5	Delta Aquarids.
445	1930—July	28.70	341.0	—17.0	26	G	M	35.7	Delta Aquarids.
446	1930—July	29.68	27.0	—11.0	3	F	M	36.7	? 464.
447	1930—July	29.68	341.7	—15.7	21	G	M	„	Delta Aquarids.
448	1930—July	29.68	346.0	—26.0	4	G	M	„	Alpha PsA.
449	1930—July	29.68	355.0	—40.0	3	F	M	„	424; D. 275, 1.
450	1930—July	28-29	3.0	—21.5	5	G	M	36.2	Beta Cet.
451	1930—July	28-29	10.0	—34.0	7-8	F	M	„	? 457; AMS 547.
452	1930—July	28-29	308.0	—10.0	8	F	M	„	Cap. I.
453	1929—July	30.65	343.5	—15.5	12	G	M	37.4	Delta Aquarids.
454	1930—July	30.68	343.0	—30.0	5	P	M	37.7	Alpha PsA.
455	1930—July	30.68	344.0	—15.5	14	G	M	„	Delta Aquarids.
456	1930—July	31.70	2.5	—19.5	2	P	M	38.7	Beta Cet.
457	1930—July	31.70	17.0	—35.0	3-6	P	M	„	? 451.
458	1930—July	31.70	37.0	—37.5	3-5	F	M	„	
459	1930—July	31.70	343.0	—29.0	5-6	F	M	„	Alpha PsA.
460	1930—July	31.70	344.5	—15.0	22	G	M	„	Delta Aquarids.
461	1930—July	31.70	346.0	—22.0	5-7	G	M	„	475.
462	1930—July	31.70	351.0	+ 5.0	5-6	P	M	„	Iota Psc.
463	1929—July	31.71	6.0	—20.0	3	F	M	38.4	Beta Cet. ?
464	1929—July	31.71	33.0	—14.5	3	F	M	„	? 446.
465	1929—July	31.71	49.0	+22.0	4	G	M	„	492, 511.
466	1929—July	31.71	66.0	—42.0	4	P	M	„	481, ? 494.
467	1929—July	31.71	342.0	—33.0	9	F	M	„	Alpha PsA.
468	1929—July	31.71	344.5	—15.0	9	G	M	„	Delta Aquarids.
469	1929—Aug.	1.45	343.0	—18.0	3-5	G	B	39.7	Inc. 1 stn.
470	1929—Aug.	1.45	347.5	—14.0	6	G	B	„	Delta Aquarids.
471	1930—Aug.	1.68	6.0	—41.0	4	F	M	39.5	84.
472	1930—Aug.	1.68	39.0	— 1.5	5	F	M	„	510.
473	1930—Aug.	1.68	51.0	—40.0	5	F	M	„	
474	1930—Aug.	1.68	317.0	—22.5	10	G	M	39.5	? 497, ? 549.
475	1930—Aug.	1.68	345.0	—24.5	7	G	M	„	461.
476	1930—Aug.	1.68	346.0	—14.0	11	G	M	„	Delta Aquarids.
477	1930—Aug.	1.68	352.0	+ 3.5	4	G	M	„	Iota Psc.
478	1929—Aug.	1.69	7.5	—21.0	5-7	G	M	39.4	Beta Cet.
479	1929—Aug.	1.69	52.0	—24.0	3	P	M	„	
480	1929—Aug.	1.69	54.0	+ 1.0	4	F	M	„	493, D. 49, 2.
481	1929—Aug.	1.69	64.0	—41.5	4-6	F	M	„	466, ? 494.
482	1929—Aug.	1.69	342.6	+32.2	5	G	M	„	Alpha PsA.
483	1929—Aug.	1.69	345.7	—14.5	19	G	M	„	Delta Aquarids.
484	1929—Aug.	1.69	350.5	+ 2.5	6-7	G	M	„	Iota Psc.
485	1929—Aug.	1.69	359.0	—21.0	3-4	G	M	„	Beta Cet.
486	1931—Aug.	2.39	343.0	—16.0	3-4	F	G	39.6	Delta Aquarids.
487	1929—Aug.	1-3	67.0	—31.0	4	G	M	40.3	
488	1929—Aug.	3.66	2.5	—20.0	4-6	F	M	41.3	Beta Cet.
489	1929—Aug.	3.66	22.0	+18.0	3	P	M	„	508, D. 16, 1; 16, 3; AMS 68, AMS 588.
490	1929—Aug.	3.66	27.0	+21.0	5	F	M	„	D. 27, 5; AMS 594, 206.
491	1929—Aug.	3.66	39.5	—15.5	10	G	M	„	509; Comets 1852ii and 1877ii.
492	1929—Aug.	3.66	48.0	—21.0	5-6	G	M	„	D. 34, 1; NZ 465, 511. 531.
493	1929—Aug.	3.66	55.0	+ 2.0	3	F	M	„	480, D. 49, 2.
494	1929—Aug.	3.66	75.0	—41.0	4	F	M	„	? 466, ? 481.
495	1929—Aug.	3.66	303.5	—10.5	7	G	M	„	Alpha Cap.
496	1929—Aug.	3.66	319.0	—16.0	6	G	M	„	Iota Cap.

TABLE 2.—List of Radiant Points Observed—Continued.

			Radiant.						
No.	Date.	G.M.T.	R.A.	Dec.	Mets.	Wt.	Obs.	L.	Remarks.
			°	°				°	
497	1929—Aug.	3.66	324.0	—23.0	7	P	M	41.3	? 474, D. 252, 11; 249, 11; 252, 9; AMS 1125, 1483, 1485.
498	1929—Aug.	3.66	335.0	—45.5	3	F	M	„	
499	1929—Aug.	3.66	337.5	+12.5	4	G	M	„	D. 261, 11; 261, 15.
500	1929—Aug.	3.66	346.0	—33.0	12	G	M	„	Alpha PsA.
501	1929—Aug.	3.66	347.3	—13.7	17	G	M	„	Delta Aquarids.
502	1931—Aug.	4.49	342.5	—33.5	4-5	G	G	41.5	Alpha PsA.
503	1931—Aug.	4.49	348.0	—15.0	9	G	G	„	Delta Aquarids.
504	1929—Aug.	4.54	327.0	—15.3	4	G	B	42.1	? Iota Cap.
505	1929—Aug.	4.54	321.0	— 2.0	3	G	B	„	Beta Aqr.
506	1929—Aug.	4.66	0.5	—23.5	4	F	M	42.2	Beta Cet.
507	1929—Aug.	4.66	9.0	—12.5	5	G	M	„	542, D. 4, 2.
508	1929—Aug.	4.66	23.0	+16.0	3	F	M	„	489.
509	1929—Aug.	4.66	39.0	—16.0	4-5	G	M	„	491, Comets 1852ii, 1877i.
510	1929—Aug.	4.66	39.0	+ 1.0	3	F	M	„	472.
511	1929—Aug.	4.66	49.0	—21.0	2-3	F	M	„	465, 492, ? 531.
512	1929—Aug.	4.66	304.0	—10.5	2	F	M	„	Alpha Cap.
513	1929—Aug.	4.66	333.5	— 0.5	4	F	M	„	Zeta Aqr. Inc. 1 stn.
514	1929—Aug.	4.66	347.0	—33.0	4	P	M	„	Alpha PsA.
515	1929—Aug.	4.66	348.5	—13.3	10	G	M	„	Delta Aquarids.
516	1931—Aug.	2-4	304.0	—11.0	7	G	G	40.5	Alpha Cap.
517	1931—Aug.	5.44	321.0	— 9.0	13	G	G	42.5	Beta Aqr.
518	1931—Aug.	5.44	322.0	—17.5	13	G	G	„	Iota Cap.
519	1931—Aug.	5.44	336.0	—13.0	9	G	G	„	Sigma Aqr.
520	1931—Aug.	5.44	350.0	—14.0	4-5	G	G	„	Delta Aquarids.
521	1931—Aug.	6.47	288.5	—45.5	3	F	G	43.5	
522	1931—Aug.	6.47	319.5	— 6.5	3	F	G	„	Beta Aqr.
523	1931—Aug.	6.47	349.5	—14.0	10	G	G	„	Delta Aquarids.
524	1931—Aug.	5-6	297.0	—22.0	8	P	G	„	525, ? 63.
525	1931—Aug.	7.51	297.0	—22.0	6	F	G	44.5	524, ? 63.
526	1931—Aug.	7.51	324.0	—14.5	6	G	G	„	Iota Cap.
527	1931—Aug.	7.51	336.0	0.0	4	G	G	„	Zeta Aqr.
528	1931—Aug.	7.51	351.0	—19.5	3	G	G	„	d1 Aqr.
529	1931—Aug.	7.51	352.0	—12.5	12	G	G	44.5	Delta Aquarids.
530	1929—Aug.	8.67	6.0	+12.5	4	G	M	46.1	D. 3, 7; 3, 10.
531	1929—Aug.	8.67	43.5	—27.0	4	G	M	„	? 511, ? 492.
532	1929—Aug.	8.67	271.0	--34.5	1	G	M	„	1 stn.
533	1929—Aug.	8.67	321.0	— 6.0	3	F	M	„	Beta Aqr.
534	1929—Aug.	8.67	350.0	—30.5	5	G	M	„	Alpha PsA.
535	1929—Aug.	8.67	352.3	—11.5	8	G	M	„	Delta Aquarids.
536	1931—Aug.	9.56	18.5	+ 2.5	3	G	G	46.5	
537	1931—Aug.	9.56	29.0	—20.0	6	G	G	„	Comet 1877ii.
538	1931—Aug.	9.56	336.5	— 1.0	5	G	G	„	Zeta Aqr.
539	1931—Aug.	9.56	340.3	—26.7	7-8	G	G	„	Alpha PsA.
540	1931—Aug.	9.56	352.0	—21.5	6	G	G	„	d1 Aqr.
541	1931—Aug.	9.56	352.5	—12.0	10	G	G	„	Delta Aquarids.
542	1929—Aug.	12.68	9.5	—14.0	3-4	G	M	50.0	507.
543	1929—Aug.	12.68	22.5	— 7.5	4-5	G	M	„	D. 24, 1.
544	1929—Aug.	12.68	80.0	—42.5	4	F	M	„	
545	1929—Aug.	12.68	326.0	—35.4	5	G	M	„	? 559, AMS 1493.
546	1929—Aug.	12.68	330.7	—13.4	5	G	M	„	Sigma Aqr.
547	1929—Aug.	12.68	350.0	—21.5	1	G	M	„	d1 Aqr.
548	1931—Aug.	13.52	11.0	—30.5	10	P	G	50.2	557.
549	1931—Aug.	13.52	314.0	—23.0	5-6	G	G	„	? 474, ? 497.
550	1931—Aug.	13.52	335.0	—13.0	5	G	G	„	Sigma Aqr.
551	1931—Aug.	13.52	336.5	—26.0	3-6	F	G	„	75.
552	1931—Aug.	13.52	350.5	— 5.7	7-9	G	G	„	BAA 1103 ?, AMS 1191 ?
553	1929—Aug.	13.67	350.0	—60.0	3	P	M	51.0	? 78, D. 269, 1.
554	1929—Aug.	13.67	350.0	—22.0	2-4	F	M	„	? 77, d1 Aqr.

TABLE 2.—LIST OF RADIANT POINTS OBSERVED—Continued.

No.	Date.	G.M.T.	Radiant. R.A.	Radiant. Dec.	Mets.	Wt.	Obs.	L.	Remarks.
555	1929—Aug.	12-13	2.5	—36.0	6	G	M		
556	1929—Aug.	12-13	14.0	—42.0	6	P	M	"	
557	1931—Aug.	14.50	11.5	—33.0	3	P	G	51.2	548.
558	1931—Aug.	14.50	23.7	—15.0	1	G	G	"	1 stn.
.559	1931—Aug.	14.50	327.0	—30.0	7	G	G	"	? 545.
560	1931—Aug.	21.66	39.0	+ 9.5	5	G	G	58.3	
561	1931—Aug.	21.66	52.5	— 9.5	3	G	G	"	567; Comet 1596, 1845iii.
562	1931—Aug.	21.66	61.0	— 2.5	5	G	G	"	
563	1931—Aug.	21.66	81.5	— 7.5	1	G	G	"	1 stn.
564	1931—Aug.	21.66	103.0	—50.3	4	G	G	"	
565	1929—Aug.	31.57	11.0	—17.0	3	G	M	68.8	? D. 14.
566	1929—Sept.	1.66	44.8	—19.7	4	G	M	69.8	? D. 34.
567	1929—Sept.	1.66	55.0	—11.5	5	G	M	"	? D. 51, 7; NZ 561; Comet 1845iii.
568	1930—Sept.	22.67	82.0	+15.0	3-5	F	M	90.3	
569	1930—Sept.	22.67	84.0	+ 4.0	1-3	F	M	"	
570	1931—Oct.	2.51	28.7	— 9.5	4	P	G	99.3	
571	1931—Oct.	2.51	55.0	— 5.0	4	G	G	"	
572	1929—Oct.	5.61	41.4	— 2.3	6	G	M	102.8	D. 41, 3.
573	1929—Oct.	5.61	59.1	—13.2	6	G	M	"	D. 51, 9; 51, 10.
574	1929—Oct.	5-6	67.6	+ 7.3	8	G	M	103.3	See D. 57.
575	1929—Oct.	5-6	74.0	—52.5	4	F	M	"	
576	1929—Oct.	5_6	98.0	+15.0	5	F	M	"	D. 79.
577	1931—Oct.	16-61	31.5	—12.0	3-4	F	B	113.2	
578	1931—Oct.	16.61	59.0	— 8.5	3-4	G	B	"	Comet 1580.
579	1931—Oct.	16.61	86.0	—16.0	6	G	B	"	D. 71, 3; ? 100.
580	1931—Oct.	16.61	96.0	—17.0	3	P	B	"	Alpha CMa.
581	1931—Oct.	16.61	96.0	—16.0	4	P	Bu	"	Alpha CMa.
582	1931—Oct.	22.65	98.0	+15.3	3	F	M	119.1	Orionids.
583	1931—Oct.	22.65	99.0	—17.0	3	P	M	"	Alpha CMa.
584	1931—Nov.	15.64	115.0	— 9.3	1	G	M	143.0	1 stn.
585	1931—Nov.	18.62	150.7	+21.4	4	G	G	146.0	Leonids.
586	1931—Dec.	3.51	73.5	+12.0	3	F	G	160.8	AMS 417.
587	1931—Dec.	3.51	117.0	—40.0	6	G	G	"	592.
588	1931—Dec.	3.51	122.0	—50.8	5	G	G	"	
589	1931—Dec.	4.51	65.0	— 8.3	2	G	G	161.8	I stn.
590	1931—Dec.	4.51	92.3	+19.5	4	F	G	"	AMS 295.
591	1931—Dec.	4.51	113.0	—44.8	5_6	G	G	"	Sigma Pup.
592	1931—Dec.	4.51	118.3	—40.8	3	F	G	"	587.
593	1931—Dec.	3-4	102.0	+27.5	2	P	G	161.3	Geminids.
594	1931—Dec.	3-4	102.3	—48.2	5	G	G	"	? 124.
595	1931—Dec.	3-4	147.0	—47.5	5	G	G	"	
596	1931—Dec.	10.54	82.5	—28.8	1	G	G	167.5	1 stn.
597	1931—Dec.	10.54	113.0	—41.7	4-5	F	G	"	Sigma Pup.
598	1931—Dec.	10.54	127.1	— 3.3	4	G	G	"	
599	1931—Dec.	10.54	130.0	—33.0	3	G	G	"	125.
600	1931—Dec.	10.54	131.0	—62.0	2-4	G	G	"	
601	1929—Dec.	12.64	117.0	—47.5	3	F	M	170.5	Sigma Pup.
602	1931—Dec.	13.62	101.0	+28.5	5	G	M	170.9	Geminids.
603	1931—Dec.	28-30	120.0	—21.5	5	F	G	—	

In the remarks column, D refers to Denning's General Catalogue of Meteor Radiants, the first figures to the group, the final ones to the radiant number; AMS refers to the various lists of the American Meteor Society; BAA to the Meteor Memoirs of the British Astronomical Association; numbers without letters prefixed, or in some instances with NZ, refer to the radiants of the Meteor Section of the N.Z. Astronomical Society.

TABLE III.

Magnitudes of Meteors (Percentages).

Year.	Obs.	>1	1	2	3	4	5	6	Total.
1925-28		4.44	14.87	15.69	22.15	24.70	14.05	4.14	2321
1929	M	3.46	15.20	19.13	20.47	18.13	17.61	6.00	1500
1929	B	—	11.32	8.49	18.87	37.74	21.70	1.88	106
1930	M	3.85	13.76	16.12	16.72	18.93	22.34	8.28	676
1931	G	4.37	9.34	16.60	20.77	26.21	16.53	6.18	1488
1931	M	6.98	18.77	19.21	15.72	16.16	20.97	2.19	229
1931	B	—	6.00	20.00	6.00	36.00	30.00	2.00	50
Average		4.11	13.55	16.80	20.44	22.89	16.84	5.37	6370

Average magnitude of all meteors observed, 3.0.
Average magnitude of meteors fainter than mag. 0, 3.3.

TABLE IV.

Colours of Meteors (Percentages).

Year.	Obs.	Red.	Orange.	Yellow.	Green.	Blue.	White.	Total.
1925-28		9.93	1.92	2.03	1.92	5.32	78.88	1823
1929	M	8.55	5.50	2.53	4.28	4.99	68.15	1146
1930	M	4.02	3.60	1.05	1.48	5.61	82.24	473
1931	M	1.70	3.40	2.28	2.84	5.11	84.67	176
1931	G	10.69	5.65	0.25	2.17	6.69	68.55	1151
1929-31	B	2.63	0.66	—	6.58	4.60	85.53	152
Average.		8.70	3.80	2.99	2.66	7.15	74.70	4921

Percentage of meteors coloured, 25.30.

TABLE V.

Durations of Meteors (Percentages).

Year.	Obs.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	>1.0	Total.
1929-31	B	—	11.5	12.1	—	30.2	—	8.4	7.7	—	14.7	15.4	156
1931	G	2.8	13.6	11.9	16.6	15.7	13.7	8.8	6.1	2.0	3.4	5.4	1416
1925-31	M	2.2	5.6	17.7	25.5	19.7	9.0	7.8	5.3	0.3	4.8	2.1	3238
Average		2.3	8.1	15.8	22.1	18.9	10.1	8.1	5.6	0.8	4.7	3.5	4805

N.B.—B's observations were recorded in quarter seconds.

Average duration of all meteors, 0.527 secs.

Average duration of meteors less than 1.1 secs., 0.483 secs.

TABLE VI.

Length of Flight (Percentages).

Year.	Ob.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
1931	G	0.5	1.7	6.0	14.5	14.4	16.5	11.3	8.9	7.0	5.6	3.4
1925-31	M	0.3	0.6	2.9	5.0	7.1	8.7	8.8	8.7	6.4	6.2	5.8
All		0.4	1.0	3.9	8.2	9.5	11.3	9.6	8.7	6.6	6.0	5.0

Year.	Ob.	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	>20°
1931	G	2.1	1.6	0.9	1.1	0.5	0.4	0.3	0.2	0.4	0.3	2.4
1925-31	M	5.2	5.4	3.1	2.9	3.5	2.8	2.6	2.3	1.3	1.7	8.7
All		4.2	4.1	2.4	2.3	2.5	2.0	1.9	1.6	1.0	1.2	6.6

Average length of flight, all meteors, 9.98°
Average length of flight (< 1.1 secs.), 7.97°
Apparent velocity, all meteors, 18.9° per second.
Apparent velocity, meteors < 1.1secs., 16.4° per second.

TABLE VII.

MAGNITUDE-DURATION RELATION.

	All Meteors.				Meteors less than 1.1 secs.			
	Geddes.		McIntosh.		Geddes.		McIntosh.	
Mag.	Dur.	No.	Dur.	No.	Dur.	No.	Dur.	No.
>1	0.869s	58	0.800s	93	0.488s	43	0.642s	80
1	0.596	136	0.630	339	0.497	121	0.589	327
2	0.574	238	0.515	407	0.484	216	0.495	398
3	0.529	303	0.480	441	0.486	292	0.465	436
4	0.497	386	0.467	414	0.481	380	0.461	410
5	0.438	244	0.426	445	0.428	241	0.420	444
6	0.423	92	0.412	141	0.413	91	0.412	141

TABLE VIII.

COLOUR-DURATION RELATION.

	All Meteors.				Meteors less than 1.1 secs.			
	Geddes.		McIntosh.		Geddes.		McIntosh.	
Colour.	Dur.	No.	Dur.	No.	Dur.	No.	Dur.	No.
Red	0.720s	118	0.665s	115	0.592s	101	0.597s	107
Orange	0.762	62	0.498	85	0.582	51	0.461	82
Yellow	0.758	75	0.515	38	0.550	62	0.489	37
Green	0.763	24	0.665	60	0.600	20	0.623	56
Blue	0.580	76	0.713	171	0.463	68	0.613	156
White	0.488	783	0.552	1062	0.460	762	0.535	1054

TABLE IX.

REMARKABLE METEORS.

Abnormality.	Bateson.	Geddes.	McIntosh.	Totals.	Per cent.
Stationary - - -	—	7	9	16	0.3
Variable light - -	—	—	30	30	0.6
Irregular path - -	—	3	8	11	0.2
Halting motion -	—	—	5	5	0.1
Curved path - - -	1	2	6	9	0.2
Remarkable train -	—	4	4	8	0.2
Remarkable nucleus	—	3	14	17	0.3
Trains > 2s. - -	1	18	51	70	1.4
Totals - - - -	2	37	127	166	—
Total meteors - -	156	1500	3462	5118	—
Per cent. abnormal	1.3	2.4	3.7	3.2	—

EXPLANATION OF TABLES.

TABLE I.—*Details of Observations:* This table gives details of the watches performed by the various observers, and is similar in form to the first table of the preceding report. The rate actually observed per hour (col. 6) is corrected by a factor (col. 7) which attempts to make allowance for any hindrances to observing such

as clouds or moonlight. The corrected rate (col. 8) gives the number of meteors estimated to be visible in one hour to an observer working under perfect conditions. No allowance is made for the time taken to record the observations (about half a minute per meteor in the case of the writer). The estimation of rates has not been attempted where very short watches have been made, or where the hindrance to observation was too great for any certainty to be attached to the factor.

Table II.—*List of Radiants:* The 399 radiants contained in this table have been determined mainly from meteors observed within four hours on one night, at least four produced paths intersecting within a circle 2° in diameter, or three meteors on one night and two on an adjacent night, intersecting as described above, or one stationary meteor, being required to form a radiant. In some cases radiants are included on weaker evidence where they fit in with a series of good radiants, or where they are confirmed by radiants in other catalogues.

In some minor points the arrangement differs from that of the first report. Following the I.A.U. recommendation, the longitude of the meteoric apex, L, is now included. The radiants, however, remain in order of date. The weights assigned to the radiants, good, fair, or poor, are shown in the column following that of the number of meteors. The full notes previously given have been reduced to a bare mention of the catalogue numbers of related radiants. The more prominent meteor showers are fully described in a separate in a separate section (page 435). Where they occur in this table, therefore, no remarks are given, but each is denoted by a proper name, on the lines adopted in Denning's General Catalogue. Another feature is the omission from this report of doubtful radiants (Table III in the previous report). These have been found in most instances to have been included on insufficient data, and their continued publication would serve no useful purpose.

Table III.—*Magnitudes of Meteors:* This table of the observed magnitudes of meteors reveals that the meteors increase in numbers with decrease of brightness, until the fainter magnitudes are reached, where many meteors are undoubtedly missed because of their extreme faintness.

Tables IV, V, and VI.—*Colours, Durations, and Length of Flight:* These tables are designed to show the average appearance and range of variation of these features in the meteors observed.

Table VII.—*The Magnitude-Duration Relation:* This table reveals strikingly that average duration decreases with loss of brightness. Geddes has pointed out that the curve resulting from plotting these data closely resembles one arm of a parabola.

Table VIII.—*Colour-Duration Relation:* An interesting table in the first report of the American Meteor Society *(Trans. Amer. Phil. Soc.,* 22, pt. i) prompted the formation of a similar table from the data available. While supporting Dr Olivier's figures of the low average duration of yellow and orange meteors and the high average shown by blue and green meteors, the present table does not confirm his contention that the white meteors have the longest duration of all. The difference has probably arisen from the fact that where he used only meteors actually classed as white by the observer, in the present table any meteor not assigned a colour and brighter than the fifth magnitude (i.e., in which colour should have been seen if it were present) has been regarded as white.

In the preceding statistical tables a distinction has been drawn wherever possible between normal and abnormal meteors, the view being taken that any meteor with a duration greater than 1 sec. is not normal. This distinction has generally resulted in smoothing out irregularities in the data.

Table IX.—*Remarkable Meteors:* It may come as a surprise to the uninitiated that only three meteors in a hundred present any marked abnormality. In the table the various types of abnormality are shown.

Fireballs.

During the period covered by the report six bright fireballs, four of which were of the detonating variety, have been subjected to special study. The results have been published separately as follows:

Fireball of 1929, September 5, in *Journ. B.A.A.,* 40, p. 79.

Fireball of 1929, October 7, in *Journ. B.A.A.,* 40, p. 301.

Fireballs of 1930, June 13 and 18, in *Journ. B.A.A.,* 41, p. 73.

Fireballs of 1930, July 30, and 1931, February 19, in *Journ. B.A.A.,* 42, p. 174.

In the course of collecting fireball observations through the New Zealand press and in other ways, a number of isolated reports of bright objects have been received. Special acknowledgment must be made of the assistance rendered by the following persons:—Mrs M. E. Allen, Eketahuna, press clippings; Mrs R. A. McIntosh, Auckland, apparent paths; J. W. Alexandre, Auckland, two daylight fireballs and several other objects; A. C. Gifford, Silverstream, observations; Dr C. E. Adams and I. L. Thomsen, Dominion Observatory, for making available observations of fireballs forwarded to the observatory.

Although it has been impossible to determine real paths for these objects, they have a definite value in determining rates of frequency and times of apparition. It has been found, for instance, that the monthly frequency reaches a marked maximum in June, the scanty data thus revealing a similarity to the curve of meteor rates, whereas in the northern hemisphere the curves are opposed.

MONTHLY FREQUENCY.

Month.	Number.	Month.	Number.	Month.	Number.
January	1	May	2	September	6
February	4	June	14	October	3
March	2	July	9	November	3
April	5	August	5	December	0

A study of the distribution of these fireballs in time shows a marked maximum in the evening hours and a scarcity after midnight, already well established in the data compiled in the northern hemisphere. Two daylight fireballs are not included in the table.

DISTRIBUTION IN TIME.

Hour.	17–18	18–19	19–20	20–21	21–22	22–23	23–24
No.	2	7	1	8	11	11	4

Hour.	0–1	1–2	2–3	3–4	4–5	5–6
No.	2	1	1	0	2	1

CONCLUSION.

Further statistical data, notably on trains and telescopic meteors, are being tabulated from the observations now in hand, but treatment of these data is withheld at present owing to the scanty material available for discussion.

In conclusion the Director would appeal to members of the New Zealand Astronomical Society to endeavour to contribute to the work being undertaken by the Meteor Section. If disinclined to actively observe meteors, there are many other ways in which assistance can be rendered. Variable-star observers and comet seekers can materially assist by recording all telescopic meteors seen. Possessors of moderate telescopes can spend a few hours at the time of rich annual showers sweeping radiant areas in a search for telescopic meteors. Any member, with little trouble to himself, can forward details of bright fireballs or initiate press campaigns for the collection of observations of such objects.

Those members of the Society not possessing telescopes, but anxious to do some research, are invited to write to the Director with a view to taking up the study of meteors, and thereby helping to maintain the section's output of observations. Every assistance will be willingly given to inexperienced observers who desire to contribute to the work being performed.

R. A. McIntosh, F.R.A.S., Director.

Private Observatory,
23 Hollywood Avenue, Epsom, Auckland,
June 7, 1932.

The Rakaia Valley.

By R. SPEIGHT, Curator of the Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 1st October, 1930; received by Editor, 1st December, 1932; issued separately, January, 1934.*]

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A.—INTRODUCTION AND STATISTICS.

The Rakaia is the largest of the rivers that belong entirely to the Canterbury area; in fact, it is surpassed in importance by only two rivers, the Waitaki and the Molyneux (Clutha), belonging to the whole extent of the eastern and south-eastern slope of the Southern Alps. Its valley, too, may be considered as typical of those in the Canterbury area, and a statement of its features should bring out many interesting details as to the general physiographical characteristics of the central portion of the province. This has only been done previously by Haast in his "Geology of Canterbury and Westland," published in the year 1879—that is, fifty years ago.

General Statistics of the River:

The following are the chief features relating to the basin of the river:—

Length	87 miles.
Length of the mountain portion of its course, from the Lyell Glacier to the Gorge Bridge	49 "
Length of the course over the plains to the sea	38 "
Length from the Lyell Glacier to the junction of the Wilberforce	30 "
Length of the Wilberforce	33 "
Distance of the junction of the Wilberforce to the Gorge Bridge	19 "
Length of the main divide drained by the river and its tributaries	45 "

Area of the basin; that is, approximately the area of the mountain portion	1547 sq. miles.
General height of the main divide: Between 6000 feet and 7000 feet, with higher points and occasional passes.	
Height of the source in the Lyell Glacier ..	3568 feet.
Height of the terminal face of the Ramsay Glacier	3354 ,,
Height of the terminal face of the Cameron Glacier	4478 ,,
Height of the terminal face of the Stewart Glacier	3584 ,,
Height Browning Pass	4752 ,,
Height Whitcombe Pass	4025 ,,
Height Mathias Pass	4700 ,,
Height Mount Whitcombe	8656 ,,
Height Louper Peak	8165 ,,
Height Malcolm Peak	8236 ,,
Height Mount Harman	6170 ,,
Height Mount Arrowsmith	9171 ,,
Height surface of Lake Coleridge	1667 ,,
Height surface of Lake Heron	2276 ,,
Height surface of Lake Lyndon (approx.) ..	2750 ,,
Height Power Station	1280 ,,
Height Gorge Bridge (approx.)	875 ,,
Height Railway Bridge	331 ,,
Height Mount Hutt	7180 ,,

B.—GEOGRAPHICAL ACCOUNT OF THE RIVER BASIN.

1. *The Main Rakaia:*

The Rakaia rises in the Lyell Glacier at a height of 3568 ft., and flows in an easterly direction for about two miles, when it crosses the terminal face of the Ramsay Glacier, coming in from the north, and flows between it and Meins Knob (4437 ft.) at a height of 3354 ft. (Photo No. 1). These two glaciers rise in the main divide of the Southern Alps, the most important peaks in the vicinity being Malcolm Peak (8236 ft.), Blair Peak (8185 ft.), Mount Whitcombe (8656 ft.), and Louper Peak (8165 ft.), and between these the divide stretches almost unbroken by any low pass, the only one worth mentioning being the Strachan Pass (5651 ft.). To the south of this part of the course of the river is high, practically unsurveyed country, whose highest named peak is Mount Goethe, though there are probably others higher still. This lies just south of the Lyell Glacier.

After leaving the face of the Ramsay Glacier the river flows almost due east for about 18 miles in a broad, open river-bed, somewhat narrow to start with, that is less than half a mile wide, but the width soon increases till it in places exceeds a mile, over which the river finds its way in braided streams. Bordering the actual river-bed are low terraces, which vary in width from nothing up to half a mile, and which are subject to inroads of the river, so that the width across which the river swings at ordinary flow is extremely variable. Also, where spurs from the neighbouring hills reach down to the valley-floor, the bed is narrowed, and the fringe of terraces may be absent or reduced to the smallest width. In this, as in other parts of its course, the river has all the characters of an aggrading stream, the grade of the bed being approximately 260 ft. per mile for the first 6 miles and 60 ft. for the last 12 of this section.

During the section just mentioned the river receives numerous small tributaries on both banks; on the south the two Washburns and the Lake Stream. The last rises on the south-eastern face of Mount Arrowsmith (9171 ft.), first flows south-east through a glaciated valley for about 15 miles as the Cameron River, and when it reaches the vicinity of Lake Heron turns and runs N.N.W. for another 11 miles to join the main Rakaia; it receives when near Lake Heron the overflow from it. At times the Cameron has discharged into and runs through this lake, and distributary streams still do so at times of heavy flood, for the river has built a wide delta-fan which embraces nearly all the western shore of the lake, and threatens to reduce its area still more. At present the Cameron follows along the northern margin of the fan, and thus avoids the lake. It is, however, bringing down a considerable quantity of waste which it is depositing across the track of the Lake Stream, thus ponding the water back, so that the level of the lake has risen by several feet, necessitating the alteration of the grade of the road round the south-west corner.

On the north side the Rakaia receives numerous streams which rise in the main divide, the most important of these being the Louper from Whitcombe Pass, and the Mathias, the latter a stream of considerable size which rises in the Mathias Pass (4700 ft.), and runs in a south-easterly direction, the latter part of its course being over an aggraded river-bed, of considerable width, like that of the Rakaia.

Just below the junction of the Mathias, the Rakaia turns its direction, and continues south-east to the sea, with slight local variations from this general direction. It receives about nine miles down on its left bank, the Wilberforce (Photo No. 2), a tributary comparable in size with the parent stream, whose features will be dealt with separately, as they present certain important peculiarities. In this part of its course, over a stretch 18 miles in length, the main Rakaia continues to occupy a broad river-bed, nearly a mile and a-half in width, once occupied by a lake now emptied partly by infilling at its head and partly by the lowering of the bar down-stream.

The floor of this old lake is marked in places by silts, which are at times beautifully varved. Moraine covers them occasionally, excellent sections which show the relations of the two being given in the cliffs which border the river-bed below the Power House. In one or two places there are islands of solid rock projecting through the gravel floor of the river-bed, e.g., Double Hill (2240 ft.), with its twin peaks, just below the junction of the Mathias; Woolshed Hill (1723 ft.), in the angle between the Rakaia and the Wilberforce;

and the mound in the river-bed between the Power House and Redcliffe Gully (1284 ft.). The country on either side of the river-bed is downy in character, its height above the water being irregular and ranging from zero up to about 700 ft. Ice-scoured surfaces are freely exposed, and there is a general covering of moraine and fluvio-morainic material irregularly disposed and of varying thickness.

The river receives on its left bank, about seven miles below the junction of the Wilberforce, a stream of some importance called the Acheron, whose low-water discharge is about 50 cusecs. It rises near Porter's Pass, at the southern end of Mount Torlesse, flows through Lake Lyndon, and continues in a south-westerly direction in a channel generally incised in the surface, joining the Rakaia after a course of some 10 miles. Lake Lyndon is about two miles in length, and is formed by the blockage of a section of a valley at one end by a fan, and at the other end by moraine. The lake was once of much greater extent, and stretched for a mile down the river valley. Lowering of the morainic barrier appears to be the reason for the shrinkage.

On the right bank the Rakaia receives numerous small streams which descend by precipitous channels from the Palmer, Black; and Mount Hutt Ranges, which bound the valley on the south. Some of these streams have developed fans in as perfect a form as any to be seen in New Zealand. Near Double Hill, examples are to be seen over five miles across their fringe, and further downstream below the Power Station they become steeper, and occasionally show a growth of one within the other. The oldest has had its fringe removed by the erosion of the main river as it crossed the fan front, and this has necessitated an adjustment of grade as the younger fans developed. In some cases the adjustment of grade has had to be renewed, and in consequence there is a nest of fans, two secondaries lying inside the primary.

At the end of this section of the course of the river it enters what is known as the Rakaia Gorge, its length being some six miles, in the upper three of which it is somewhat open, but bounded by cliffs of silts and gravels, while in the lower three the cliffs composed on volcanics and coal measures narrow in, and the river occupies the whole floor between them (Photo No. 3). It flows in well-defined meanders, deeply incised, with cliffs on either side rising to 200 ft. above water-level, and behind them flights of terraces of variable number, at most 16, but reaching a total height of 700 ft. above the river. These are capped in places by moraine, but more usually by river gravels, with moraine occasionally on top of them. In places, too, below the gorge there are lake silts such as are so typically developed in the reach above the gorge. It is uncertain whether these have been deposited in a lake or not, as it seems difficult to restore in imagination a landscape which would allow of the accumulation of water below the rock barrier lying across this part of the river course, and responsible for the ponding back of the water of the lake which occupied the reach above the gorge. It should be noted, however, that varved silts may be deposited in other places than a lake, and this may be the case here (Photo No. 4).

From the gorge onwards the river runs in a bed of the same character all the way to the sea. It varies in width from half a mile up to two miles, and the stream wanders on this bed in braided streams, between banks which get progressively lower downstream. These are 600 ft. in height near the gorge, but by the time the river has reached the railway they have diminished in height till they are at most from 12 ft. to 15 ft. high, and when they reach the sea they are lower still. In many places they fall directly to the water-level, but usually they exhibit a flight of terraces of varying width. Near the railway the main terrace is distant nearly four miles from the present position of the stream, and the base of the terrace is at a lower level than the water, indicating that it is aggrading its bed at the present time.

Some of the islands in the stream, especially in its lower part, are of considerable extent, up to five miles in length, and in favourable positions they are cultivated, but usually they have a covering of grass and scrubby bushes. These islands are specially subject to attacks by the stream when it is high, and hundreds of acres have been washed away, and again what was formerly river-bed is passing through various stages in its development into land of value for pastoral and ultimately for agricultural purposes. A noticeable feature of many of the temporary islands in the river-bed is the close covering of lupins. These obstruct the rush of water in flood time, and intercept the silt from the muddy river, building up the island, and, of course, obstructing the ready get-away of the water. Being of loose material, they are, however, readily destroyed, and there is thus a distinct loss, for the lupins by their decay tend to furnish humus for the soil, and the nitrifying nodules in their roots would greatly improve it were there any simple and economical means of conserving it.

Throughout this stretch of the river's course the banks are almost entirely of shingle, the only place where solid rock shows being at the Curiosity Shop, about three miles below the gorge, where at the foot of a high terrace there is an outcrop of Tertiary beds, consisting of sands and calcareous sandstones, the last named being a notable bed for fossils.

In the higher part of the plains near the hills the gravels are covered by moraine and fluvio-morainic material, clearly indicating that the plains had practically their present form when the ice extension was at its maximum. There is no indication of morainic matter interstratified with the gravels, but there is evidence from the increased oxidation of the lower parts exposed near the gorge, and the marked contrast in colour between this part and the upper portions, that the lower gravels belong to a much older period of deposition, perhaps pre-glacial in time. All through this stretch the river receives no tributaries, except in the immediate vicinity of the gorge, and the only addition to its volume is the rain falling directly into it or any seepage which comes from the banks.

2. *The Wilberforce* (Photos Nos. 2 and 5):

The basin of the Wilberforce presents numerous interesting geographical and geological problems. The river rises in the main divide near Pope's Pass (5290 ft.), about a mile to the east of Mount Harman (6170 ft.), and flows W.S.W. practically parallel with the range for a distance of three miles to the neighbourhood of Browning Pass (4752 ft.), where it is joined by two streams, Hall Creek and Grave Creek, then it turns and flows S.S.W. for a distance of seven miles, where it receives a large tributary on its right bank (height 2333 ft.), variously called Stewart or Unknown Stream. This has three main tributaries, all of which reach back to the main divide and rise in glaciers, the valleys being rather narrow, but easily traversed. In the reach just mentioned the Wilberforce has two other tributaries worth mentioning, viz., the Gifford on the right and the Cronin on the left bank, both of which rise in glaciers of no great size. The river-bed is here somewhat confined, but easy to traverse, and it has a grade of approximately 110 feet per mile.

Opposite the junction with Unknown Stream, the river rounds an ice-scoured bluff, called Sebastopol, and then runs S.S.E. for 13 miles in a wide river-bed, in places over a mile wide, in braided streams on a grade of 50 ft. per mile. Halfway down this reach it receives on its right bank the Moa Stream, which has considerable volume, since it drains a large area of high country between the Wilberforce and the Mathias, with peaks running up to over 7000 ft. The head of this stream forms a large basin or amphitheatre, and the sides are marked with hanging valleys. Numerous other streams of smaller size come in on either bank of the Wilberforce. The walls of the valley are steep, and the cross-section is typically that of a valley which has experienced a somewhat severe glaciation.

At the end of this section the Wilberforce receives on its left bank the Harper River, its largest tributary (Photo No. 5). This has a normal flow of about 400 cusecs. It rises in the Cass Saddle, 15 miles E.N.E., and flows in almost a straight line in a narrow valley, receives various tributaries on its north bank, and is joined about six miles from the Wilberforce by a large stream, the Avoca, which comes in on the right bank. This rises in small glaciers on the south-eastern side of Mount Greenlaw (7500 ft., approx.), some six miles east of the main divide, and well within the area which experiences heavy westerly rains. The river flows in a fine glaciated valley, and a small lake called Lillian discharging to the Harper lies near the southern end of the valley.

The Harper River flows almost due west to junction with the Wilberforce, but it has been partially diverted into Lake Coleridge in order to maintain the supply of water for power purposes. The original discharge from the lake by the Lake Stream to the Harper is utilised completely, so that below the Avoca the Harper receives no substantial addition to its volume. However, it takes the overflow from Lake Selfe, a small sheet of water, 1¼ miles in length, which lies in a picturesque and narrow valley to the south-east.

Below the junction with the Harper Valley the Wilberforce flows for 10 miles in a somewhat confined bed between Mount Algidus (4607 ft.) and Mount Oakden (5364 ft.), first of all south-west for three miles, and then south-east for seven miles, till it joins the main Rakaia at a height of 1260 ft. The grade of the river in this stretch is about 38 ft. to the mile.

Throughout the whole course of the Rakaia and its main tributaries the river is completely graded; no waterfalls and no rapids interfere with the general gradient, steep though it is. There are indications, too, that the stream has reached base level, for parts of it are actually building up the bed. This is clearly shown at the railway bridge, for this has not the clearance that it had when first erected. The conditions thus resemble those of the adjacent river, the Waimakariri, a description of which has been given by the present author in connection with the operations of the Waimakariri Trust (1928, pp. 199-229).

3. *Lake Coleridge* (Photos Nos. 6, 7, 8):

This is the largest lake in the basin of the Rakaia. It is nearly 11 miles long, with a general average width of 1½ miles, but with a maximum of just over two miles, lying in a N.N.W.-S.S.E. direction between two well-defined narrow mountain ridges, of which the highest peaks on the east are Mount Cotton (4345 ft.) and Kaka Hill (3283 ft.), and the highest on the west are Mount Oakden (5364 ft.) and Peak Hill (4083 ft.). The height of the surface was originally determined as 1667 ft., but the datum level of the Public Works Department is 1670 ft. Its water supply is maintained by small streams which discharge from the high country on either side. Through a break in the eastern ridge two miles wide, about midway along the lake, it receives its most considerable inflowing stream, the Ryton, as well as two smaller ones called the Simois and Scamander. The first drains Lakes Evelyn, Ida, and Catherine, all in the vicinity of Mount Ida (5575 ft.), and small in size, each having an approximate length of about a mile. There are a number of other small lakes and ponds draining to Coleridge, the most notable being Lake Georgina, which occasionally overflows to the Scamander, and the Red Lakes, situated in a deep, narrow gully near the Red Hill (5377 ft.), which discharge by way of Coleridge Creek into the southern end of the lake. As the area is a somewhat dry one, lying between the belt usually affected by north-westerly rains and that which experiences south-west and south-east rains, the supply of water to the lake is comparatively small, and this has presented at times serious difficulties in maintaining a high enough level for hydro-electric power purposes. This was the reason for turning the Harper River and also the Acheron into the lake.

The rainfall at the Power House is on the average 31-55 inches per year (average for 1913-31), as compared with that of 170 inches near the main divide (Arthur's Pass, 1923-31).

The lake is very deep, Haast obtaining soundings of over 700 ft. in the narrow part between the peninsula and the slopes of Mount

Oakden. The writer also got depths of over 400 ft. off the peninsula, that being the total length of line available at the time.

The shores of the lake have very few indentations, and the hills run down steeply into deep water, as can be seen when looking down on it from neighbouring heights, its pellucidity rendering it clear to great depths. Only on the eastern side is there any indentation of moment, for a projection halfway down called the Peninsula extends for some distance into the lake, and on either side of this are sheltered bays. Between this peninsula and Mount Oakden, right out in the lake, is a small islet, a few square yards in area, just projecting above lake-level, and surrounded on all sides by deep water. These are the only breaks in outline or in surface that the lake shows.

The lake shallows to both ends, towards the north owing to the fan of the Harper River, and possibly that of the Wilberforce. At the southern end it is rockbound, but with a certain quantity of detritus brought in by small streams, and also deposited by the lake itself. The north-westerly winds blow right down the lake, raise waves of tolerable size on it, sufficient at times to be dangerous to a boat, and these have swept a considerable quantity of material to the southern end, and built up a deposit on the rock bottom which slopes gradually beneath the waters of the lake. The width of this shore deposit exceeds a quarter of a mile. The rock barrier is capped on the southern end of the Peak Hill ridge on the west side of the lake by morainic and fluvio-morainic material. This is best developed between the Power House and the lake. It is only a mantle in most places, for both tunnels to tap the lake passed through a considerable length of solid rock, but north-west of the line of the tunnel it is probable that the barrier at lake-level is composed of unconsolidated debris, deposited in a channel formed by the ice which once came down the lake and overflowed towards the Rakaia past the end of Peak Hill. When the level of the lake was raised artificially by the dam near the outflow at the Harper end, springs near the Power House gave a more copious discharge, which suggests that they received additional water in consequence of raising the lake-level. The unconsolidated material is obviously glacial, for scratched stones are quite commonly contained in it, and glacially striated surfaces occur freely in its vicinity.

Around the margin of the lake there is a well-marked beach about 60 ft. above the level of the surface of the lake as it stood before it was used for power purposes. This was well developed on the east side near the point of the Peninsula, and also along the stretch of the shore formed of glacial materials. On the hard, steep sides of the hills it does not show. It is noteworthy that there is an old discharge channel, now quite dry, leading from the south-west corner of the lake to the Acheron, and followed by the present road for a couple of miles. The highest point of this channel is just 60 ft. above lake-level, so that if it were raised by this amount it would discharge in that direction again. An explanation of this will be given later.

A special feature of the lake shore is the spit on the south-western side about half a mile from the end of the lake. This has been described by the present author (1913, pp. 331-5). After the paper was written, the level of the lake was raised by the dam at the outflow end, and the shrubs and other vegetation on the spot were killed by drowning. A new spit was formed, based on the new level of the lake (Photo No. 7).

Along the western shore where it is bordered by cliffs of glacial debris (Photo No. 8) there is a marked transference of shingle along the shore, due to the waves which are raised in the lake by the strong north-westerly winds. It has accumulated in considerable quantity near the intake, due to interference with the alongshore movement by a groin. The new intake, which is placed in water 60 ft. deep well out in the lake, is threatened with interference from this cause. The transporting effect of the waves is very noticeable; pebbles can be seen to be moved along by each successive wave, and when the spoil from the intake tunnel was tipped into the lake it was rapidly carried along shore and very soon appeared on the beach at the southern end of the lake, over a mile away. This was first of all moved along shore, and then along the spit just referred to, and after that transported directly from the end of the spit to the beach, a distance of nearly half a mile across water which was 18 ft. deep, without any apparent filling effect on the lake. The pebbles forming the beach were up to one inch in length, and there is no doubt of the source of supply, for the tunnel has been driven in hard, dark-coloured slaty greywacke which can be readily identified. Its transport under the circumstances I have mentioned emphasises the carrying power of waves in a lake, in a situation which cannot be helped by tides and by currents other than those generated by the waves themselves.

Owing to the lowering of the lake by the undue drain on it for power purposes, the old spit just referred to is completely exposed. This has three hooks on its inner margin, and a channel at the end across which beach material was formerly transported. When the level of the lake was artificially raised, a new spit was built on the older one. This is composed of much coarser material, moderately well rounded, and with three hooks on the inner margin and a knob at the end. This spit forms a well-defined bank about two feet in height along the outer margin of the old spit.

When one sees the ordinary sub-surface beach exposed one is surprised at the size of the stones transported by the waves of the lake. These are up to seven inches in diameter, and judging from the accumulation at the intake, they must be transported somewhat rapidly. In some cases the movement of shingle has resulted in the formation of barrier-beaches, which are well exposed when the lake shows abnormal low level.

C.—PRE-GLACIAL GEOLOGICAL HISTORY.

The main features of the Rakaia Valley appear to be structural in origin. This idea was first of all enunciated by Edward Dobson (1865, p. 50 and map), who pointed out that the valleys of the

Canterbury rivers were oriented on lines, probably fault lines, diverging from a point about 40 miles due west of the town of Hokitika. This hypothesis was adopted with some reserve by Haast (1879, pp. 175-6). There appears to be some coincidence of the heads of the valleys with the lines drawn by Dobson, but too many divergencies occur, if the hypothesis is to be regarded as sound. There is also no direct evidence of the presence of these faults. Hutton (1884, pp. 91-2) considered the valleys to be of ancient date, and formed even before the Cretaceous and Tertiary sediments were deposited. He was of the opinion that the sea invaded the mountain portions, and that the limestones, etc., were laid down in them when they were arms of the sea, and he uses as a part of his main line of evidence the fact that a limestone mass in the bed of the Rakaia near Redcliffe Gully showed by its presence that erosion had taken place before its deposition. This mass of limestone turns out to be greywacke, so that the evidence and the conclusion deduced therefrom must be set aside.

The present author (1916, pp. 142-3) drew attention to certain features of the Rakaia region, notably to the series of parallel valleys which lie east of Lake Coleridge, and suggested that they were of structural origin. This is apparently the status of the question at present. It will be best, before considering this in detail, to give a brief statement of the geological history of the area, as far as it is known, up to the end of the Tertiary era. This is as follows:—Greywackes, slaty shales, argillites, with minor conglomerates of probable Triassic to Lower Jurassic age were folded at the end of the Jurassic or the beginning of the Cretaceous into a mountain range of modified Alpine type. The folding is characterised by overthrusts, faulting, and crushing, but this has not been of an intensity comparable with related movements in the European Alps, and it produced little metamorphism of the beds. The movement was evidently of a shallow depth, and its results are fracture and breaking rather than a recrystallisation of the materials under the stresses involved. This mountain range was reduced to a peneplain towards the end of the Cretaceous, a levelling probably finished off by marine planation, and on the surface thus produced a veneer of Senonian and Tertiary sediments was deposited.

1. *The Tertiary Veneer:*

The basal beds of this are Senonian in age, consisting of coal measures, but they pass up into Tertiary greensands, limestones, and shelly beds. Whether this veneer was continuous over the whole area is not known, but the presence of marine beds wherever the veneer is encountered suggests that the sea had a wide incidence, and the elevations above the surface of the peneplain, and standing above sea-level, were of small extent, even if they existed at all, although land certainly occurred in close proximity.

The remnants of this veneer are found in the valley of the Rakaia in the following places at the indicated heights:—

(a) Near Lake Heron, in the valley of the Cameron and in the Smite, at heights of approximately 2500 ft. Also on the high country west of Lake Heron, between the Cameron and the Rakaia, at a height of 4000 ft.

(b) In Redcliffe Gully, opposite the Power Station, to a height of 3060 ft.

(c) In the valley of the Harper River, just above the road crossing, and towards the head of the river, at heights in the latter exceeding 3000 ft. The former of these two occurrences consist of sands, with calcareous concretionary layers, striking E.-W. and dipping S. at low angles. The occurrence is obscured by wind-blown and glacial material, and can only be seen for a few chains on the left bank of the river. No fossils were seen.

(d) In the valley of the Acheron and Coleridge Creek, at heights of just over 3000 ft. There is besides the outlier in the lower Acheron, but this is only at a height of 1300 ft. to 1500 ft.

The widespread occurrence of these beds and their height above the floor of the valley can hardly be explained on Hutton's hypothesis that the valleys were eroded by Cretaceous times. There is also a general though not a precise similarity in the sequence in various places.

In addition to the localities just cited, Senonian beds occur in the gorge itself at heights of 900 ft. to 1000 ft., and Tertiaries at the Curiosity Shop, some three miles below the gorge, at a height of 650 feet above sea-level, but these occurrences are extra-montane, and have no apparent bearing on the origin of the mountain valley of the river.

The two areas in the vicinity of the Rakaia, where the Tertiaries are well developed and which are fairly well known, are the Trelissick Basin and Mount Somers. The general sequence in both places is similar, in that coal-measures occur at the base, and these pass up through sands, greensands, and marls into limestones and shelly beds with interstratified volcanics at various levels, but the age of the two series is not identical. In the Trelissick the lower coal-measures are definitely Senonian, and in the Mount Somers area the lowest marine beds lying immediately above the coal-measures are definitely Tertiary (Bortonian). This implies either a wider extension of the same beds as time progressed, that is, a diachronism existed, so that coal-measures of one part of the area may be synchronous with limestones in another part of the area, as maintained by Marshall (1911, p. 23), or that the same succession took place in separate diastrophic areas as suggested by Thomson (1917, pp. 399-401).

The succession of beds as developed in Coleridge Creek is apparently analogous to that in the Trelissick basin, from which it is now separated by the southern end of the Craigieburn Range, but the thickness is much less, suggesting the approximation of a shore line. It cannot be said definitely in the absence of fossil evidence that the relationship is proved, and it may, after all, be advisable to assign this case to the southern diastrophic province. The relation of the coal-measures in the Acheron River to this occurrence is, however, doubtful. The succession in Redcliffe Gully (1913, pp. 337-8) seems to belong to the Mount Somers province, so that its boundary appears to extend to just beyond the Rakaia. The occurrences of Tertiaries in the higher parts of the river basin are more definitely littoral in character, and do not have any development of the purer limestone facies. They seem more in accord with the higher beds of the two areas suggested for comparison, indicating a wider spread of the shallow water conditions, no doubt simultaneously, in Awamoan times, that being their probable age, and also that land existed in close proximity to the area where the main divide is now situated. It may be true, therefore, that this part of the area was not invaded by the sea when it extended over the outer fringe of what is now the mountain area. The fact that this facies of the Tertiaries is widespread over the deeper water deposits also indicates an actual shallowing of the sea, so that it seems to imply that the movements which culminated in the elevation of the mountain area in its present form were initiated when these beds were being deposited, that is, they date from Awamoan or Miocene times.

It is reasonable to think that the covering veneer persisted at a low level, probably submerged by the sea, till towards the close of the Tertiary era, when the shallowing of the Awamoan sea was accentuated, the area was raised, and land of some decided relief was formed. The evidence for this rise is furnished both by the Trelissick basin and by the Mount Somers area, for in both of these districts, and elsewhere in North and South Canterbury, the uppermost Tertiary beds consist of gravels which have experienced some warping, thus showing that distortional movements had not ceased when they were being laid down. These gravels definitely indicate changes in level, and also the proximity of a land of fairly high relief.

2.—MOVEMENTS AND FORMATION OF VALLEYS.

These elevatory movements were in all probability attended and succeeded by faulting, and the major physical features of the area were thus determined. The fault movements continued down to quite late geological times, and it is not certain that they have entirely finished even now, for post-glacial and recent beds are involved in dislocations, and earthquakes, such as the recent one at Arthur's Pass (1929) show that all stresses have not been satisfied. The faulting which developed towards the close of the Tertiary was oriented on two main lines, one running E.N.E.-W.S.W. and the other N.W.-S.E.

The former of these is responsible first of all for the Harper Valley, for a fault line runs up this river right to the Cass Saddle. A patch of Tertiaries occurs in the upper part of this valley (Speight, 1917, pp. 356-60), whose position can be accounted for only by faulting, probably by the differential dropping down of a narrow strip. Close alongside this line, a little above the crossing of the river by the road, is an occurrence of Tertiaries whose position may be determined by this fault—it may be determined by another fault running N.N.W. and crossing the line of the former—and across the Wilberforce, in the vicinity of Mount Algidus Station, is also a small outlier of coal-measures no doubt associated with the same dislocation, and if this line be prolonged to the south-west it will follow exactly the reach of the main Rakaia Valley between the mouth of the Mathias and the Lake Stream. This agreement in position may be only a coincidence or it may have some physiographical significance.

The next line is one concerning which there is not much evidence from the Rakaia Valley itself, but there is no doubt that the line does extend into it. It is the fault line running up the head of the valley of the Porter River (or Coleridge Creek as it used to be called, and not to be confused with the creek of that name running to the lake) in the Trelissick Basin (1917, p. 334). This extends a distance of nearly five miles for certain, the determination being based on stratigraphical evidence, and it crosses the Craigieburn Range by the Coleridge Pass, a deep nick in that otherwise unbroken range. This line, if continued with a slight deviation, would pass through the broken eastern margin of the lake, and if continued further would fall in with a well-defined depression in the Peak Hill-Mount Oakden Ridge, which suggests, though it does not substantiate, a common origin in both cases.

The next line is that associated with the gap between the Big Ben Range and the southern end of the Craigieburn Range. The lower-lying part of this mountain region appears to be associated with fault movements, since the lower country is bounded both on the north-west and the south-east by definite faults, the former running through Lake Lyndon and Porter's Pass, its line being indicated by earthquake rents of very recent date near the pass itself, and by the presence of a Tertiary outlier at the head of Coleridge Creek, whereas the south-eastern fault passes along the north-western flank of Benmore, where there is definite evidence of the Triassic greywacke beds being thrust over coal-measures towards the north-west. Further, the position of these coal-measures relative to the accompanying greywackes can only be explained by faulting. It is possible that similar coal-measures occurring in the lower Acheron Valley, as well as the beds associated with the limestones at Redcliffe Gully, may be connected in some way with this line of fault, although it is not quite clear how the position of the latter occurrence can be accounted for on this assumption (Speight, 1924, p. 626). It is more probable that it is due to an independent dislocation, as the result of which it has been thrown down from the peneplain level into a trough by faults whose direction is practically N.-S., parallel to the sides of the depression forming the saddle. In addition, the trough of the Rakaia fronting the saddle may also be due to faulting on another line, as will be mentioned later. The height of the limestones above the floor of the valley could thus be accounted for; on the other hand, it may give some measure of the overdeepening of the main valley by glaciation.

The last of this E.N.E.-W.S.W. series of faults is that running down the High Peak Valley along the northern flank of the Rockwood Range in the direction of the Selwyn Gorge (Speight, 1924 and 1928, pp. 41-2), in which the throw is considerable to the north-west, and as a result a definite fault or fault-line scarp is formed along the range. If this line were continued to the Rakaia it would almost correspond with the upstream side of the barrier at the gorge, and thus account for the hollow in that direction. The steepness of the upstream face of this obstruction supports such a contention, and it is against the hypothesis that the hollow is due to glacial excavation, since in the latter case one would expect a gentle reverse slope, analogous to the abraded side of a roche moutonnée, and specially so since this must have been near the end of the glacier where erosive power would be declining.

This fault certainly peters out before Mount Hutt is reached, since there is no break in the face of the mountain fronting the Rakaia or any other earth lineament that could conceivably be associated with an extension in that direction.

There is also a possible line of deformation extending along the base of the mountain country, both north-east and south-west from the vicinity of the gorge. Reference to the former of these directions has been made in connection with the Memoir on the Geology of the Malvern Hills (Speight, 1928, pp. 52-3), and also in the article on the Rakaia Valley Silts (Speight, 1926, pp. 56-7), and it is possible that the same line of deformation follows south-west along the front of Mount Hutt, either parallel to an axis of folding or to a fault, the face of this mountain according to this hypothesis being a fault-line scarp or a stripped surface from which tilted beds have been removed. Definite evidence of such deformation with faulting is available further south in the Mount Somers area, for the south-eastern face of Mount Winterslow and of Mount Somers are determined in this way. The trailing spurs of Mount Hutt running down to the plain are more suggestive of folding or tilting than of faulting. This supposed movement can have little bearing, however, on the valley course of the river, and its effects on the plains are largely masked at the present time by the deposit of gravel. Of course, it may have an important effect on the grade of the river, and indirectly on the cross section of the river channel.

The evidence for the other system of dislocation is unsatisfactory and largely physiographic, resting chiefly on the striking parallelism of the valleys. There is first of all the main valley of the Rakaia stretching from the vicinity of Mount Algidus downstream as far as the gorge, and, secondly, the valley of the Wilberforce and its continuation, the trough in which Lake Coleridge lies. These are continuously parallel, whereas the other valleys on the eastern side of Lake Coleridge are broken, and their continuity is not obvious. At the south-eastern end of the lake there is the valley through which the road to the Harper River and Glenthorne passes, and in which Lake Georgina lies, which may therefore be called the Georgina Valley. This is separated from Lake Coleridge by the narrow steep-sided greywacke ridge of Kaka Hill (3283 ft.), while to the east of it lies the ridge which culminates in Mount Georgina (3100 ft.). This is a double ridge, partly cut into two, with an elevated valley dividing adjacent parallel spurs, and to the east again lies a wider valley, at a higher level than the Georgina Valley, which is oriented to run east of Mount Barker toward the Acheron River, and east of that again the deep narrow trough in which the Red Lakes lie. These are bounded on the west by a narrow steep-sided greywacke ridge, and on the east by the wall-like face of the Red Hill. All these valleys and their dividing ridges are oriented on N.N.W.-S.S.E. lines.

After a break in the country to the east of the Peninsula and the middle section of the lake, the eastern series of parallel valleys is resumed towards the north-west with (i) that in which Lakes Evelyn, Selfe, and Henrietta lie, and (ii) the Lake Catherine-Avoca Valley. The former is separated from Lake Coleridge by the Cotton Sheep Range (4345 ft.), and from the latter by the Mount Ida Ridge (5575 ft., and its continuation across the line of the Harper, first Mount Gargarus, and then the Birdwood Range, which reaches a height of nearly 7000 feet for long distances, and is practically unbroken, while to the east of this valley lie Mount Enys (7202 ft.), Mount Olympus (6866 ft.), and its extension across the Harper called the Black Range. Although it is possible to connect by low-lying ground in practical alignment this last series of valleys with that lying at the southern end of the lake, this alignment may be more or less delusive, for on their common boundary, near the middle course of the Ryton, the characteristic landscape features are isolated, round, sugar-loaf-shaped hills, located as if they were fragments of a ridge formerly crossing the line of the valleys, but now dismembered by ice erosion; such are Mount Hennah, Round Hill, Goldney Hill. The ridge which divides Lake Selfe from Lake Ida appears to have been in process of dissection, and had the ice lasted longer another of these rounded hills would have been formed. This small, picturesquely situated little lake drains south-east to the Ryton. Mount Gargarus is another similarly isolated hill, and Laing's Hill, which lies further south-east, approaches this form, although it has more the nature of a slightly elongated ridge. It is divided from the Craigieburn Range to the east by a partially developed lateral valley, whose lower portion is occupied for some distance by Moraine Creek.

One feature of the eastern side of the basin, extending from the Harper River in a south-easterly direction, is the extensive, partially dissected plateau, covered with roches moutonnées, forming a shelf at the base of the high eastern wall, whose height rises to approximately 4000 ft., with the wall rising another 2000 ft. to 3000 ft. higher. This upper portion of the valley side shows a definite and regular orientation suggesting that it is a fault-scarp in origin, or if not so, that the valley sides have been scoured absolutely free from irregularities by ice action. The north-western flanks of Mount Enys and the Craigieburn Range, as well as Mount Olympus, show this feature clearly. There is also a tendency of the streams draining this eroded plateau to run parallel with and at the base of the valley wall, which suggests that they flowed alongside the margin of the glacier as it retreated from the side of the valley, leaving a narrow strip free from ice, while the other portion of the valley floor was occupied by it. The narrow valley in which the Red Lakes lie is an illustration of this, and perhaps the lower portion of Moraine Creek behind Laing's Hill is another example. These streams, parallel to the sides of the valleys and close to them, are very deeply incised, and may therefore be associated with a narrow belt of structural weakness.

A similar shelf at a lower altitude also extends along the western face of the Big Ben Range towards the Snowdon Station, and this face has features analogous to those of the bounding walls further north-west, and in addition shows practically the same alignment. It is hard to think that this correspondence is to be entirely attributable to ice erosion.

If the valleys are initially due to diastrophic movements, then their cross section seems to demand the existence of parallel faults on the eastern side, one of which determined the upper clear-cut face of the mountains, and a second one which determined the edge of the ice-eroded plateau, the former perhaps continuous for the whole length of the valley, and the latter affecting only sections of it, and especially that between the Harper and the Ryton.

In only one case do I know of geological evidence that the valleys are structural, and this may, after all, not be the authentic, viz., the Lake Selfe Valley; for the small occurrence of Tertiaries near the road-crossing of the Harper may owe its position to a fault running across the river, but all the same it may be due to the fault which follows up the river, as mentioned previously.

Although there is no definite evidence of faulting associated with these valleys, their similarity in form and arrangement suggests that they are due to some common cause, and probably some diastrophic movement. Near the gorge, faulting does occur in the gravels in its vicinity, and there is that peculiar landscape form, known as the "Railroad," whose formation seems explicable only on the supposition that it is due to faulting (Dobson and Speight, 1924, pp. 629-30). Both of these directions have the same orientation as the valleys. However, the date of the faulting is no doubt post-Tertiary, and some of it is post-glacial, and therefore it can have little or no bearing on the form of the valley antecedent to the glaciation, except in so far as it indicates a line or lines of structural weakness oriented in a direction parallel to that of the valley.

It is possible that the height of the andesite capping of Round Top as compared with the height of similar beds in the gorge of the Rakaia just above the road, a difference of some 1000 ft., may be evidence of some differential movement, or it may be merely an indication of the irregularity of the surface over which the andesite was poured. If the former is the case it would support the contention that the valley was originally a graben, and that it was bounded by two fault lines, one running N.N.W. past the western end of the Round Top ridge somewhere in the vicinity of the Switching Station, and the other more problematical still, following along the north-eastern flank of Mount Hutt, past Redcliffe Gully. It must be admitted that the direct evidence for the existence of either fault line is weak.

The only other structural feature which needs notice in connection with the Rakaia is the Lake Heron Valley, through which a distributary ice-stream went during the height of the glaciation. This runs for a distance of some 20 miles practically in a southerly direction from the Rakaia, and it is no doubt due to a diastrophic movement, judging from its form, and the position of the Tertiaries along its margins and on the high land to the west. The difference in the height of these certainly implies some differential vertical movement. There is also definite evidence of faulting with the same orientation in parts of this valley, particularly in the vicinity of the old Clent Hills homestead, but of course this merely indicates the presence of a line of weakness, which is not antagonistic to the supposition that the whole valley is due to structural causes. Its orientation is, however, somewhat off the line of either of the other dislocation directions.

Another important geological feature which may control the course of the river is the grain of the country. The general direction of the strike of the beds taking the area as a whole is N.E.-S.W., but there are local variations from this orientation by as much as 90°, and at times such a variation may persist over a considerable area. They cannot affect the direction of the river except locally. An excellent instance of the correspondence of the strike and the direction of the stream is furnished by the Upper Wilberforce, which for several miles near Browning Pass is practically parallel with the strike, viz., N.N.E.-S.S.W.

The general direction of the stream being from N.W. to S.E., it is practically at right angles to the strike, so that inequality in hardness of the beds is only likely to affect the tributaries to any marked extent, and no doubt some of the smaller tributaries are located on beds, either lithologically weak or weak as the result of the crushing and shattering which attended the folding of the beds at the time the area was being raised to form a mountain chain. A number of smaller tributaries coming from Mount Hutt seem to be dependent on this feature for their orientation.

The beds, too, are all seriously affected with jointing, but this does not appear to be regular in direction. It does, however, aid materially in the breaking down of the rocks under the action of various erosive agents.

Some of the streams may also have their directions determined by definite belts of crushing, which may grade in either direction into faults with relative vertical displacement, but when it is remembered that the greater part of the country forming the basin of the river is composed of greywackes and argillites, in which no definite horizons have yet been determined, although they will no doubt some day, it is difficult to detect faulting unless actually visible in section or unless the overlying Tertiaries are present to give some criterion of movement. In this way faults which may control the course of tributaries may be overlooked.

The relative importance of normal erosional processes and of earth movements in determining the course of the river and its tributaries is difficult to estimate. It may be that the original direction of the main stream was dependent on the course taken on the surface of the land as it rose from the sea at the close of the Tertiary with its veneer of later sediments. This would be consequent drainage, across the strike of the covering beds, and also across the general strike of the basement beds if the former were stripped off, for in general the strike of the Tertiaries is also N.E.-S.W. The correspondence of this direction of main drainage with hypothetical structural lines, oriented similarly, increases the difficulty of assigning to each its proper role, and really the main evidence for the presence of these tectonic lines with N.W.-S.E. orientation is the arrangement of the system of parallel valleys, evidence decidedly open to suspicion. However, whether due to erosional processes, or to tectonic causes, or to a combination of both, considerable changes have taken place in the direction of drainage under the influence of subsequent faulting on E.N.E.-W.S.W. lines and of glaciation. As a result of the former, all the valleys with the exception of the main Rakaia have been cut into sections, and changes in the direction of stream flow have occurred; these changes have been accentuated by the action of glaciers, and it is hard at times to say which is the major modifying cause.

D.—INFLUENCE OF GLACIATION.

1. *Changes in Drainage Directions:*

I think it may be assumed that the general valley alignments before the onset of the ice-flood were much the same as those existing now, but that some modifications have resulted from the presence of the ice. The chief of these appear to be:—

(i) The Wilberforce ran down the valley now occupied by Lake Coleridge, and joined the Rakaia by the gap now blocked with moraine, etc., between Peak Hill and the intake.

(ii) The Avoca probably ran down south-east across the general direction of the Harper, following the line of the upper waters of the Ryton. This diversion may have occurred earlier as a result of the Harper fault.

(iii) The Cameron drained to the Ashburton, and only a small stream occupied the northern end of the Lake Heron Valley, and this drained to the Rakaia in a northerly direction.

(iv) It seems reasonable also that the Upper Selwyn drained to the Rakaia, and not down the High Peak Valley through the Selwyn Gorge or through the upper valley of the Hawkins past Dalethorpe towards Sheffield.

2. *Extent of Ice and Distributary Streams:*

It will perhaps be best at this stage to consider the extent and thickness of ice which filled the valley.

The three main sources of supply came down from the main divide through the valleys of the Upper Rakaia, Mathias, and Wilberforce and their tributaries. A large supply was favoured by the length and height of the main divide, lying right across the path of the prevailing moisture-bearing winds, and also by the amphitheatre of high peaks which flanked the upper part of the valley on its north-eastern and south-western margins. The ice from these valleys was concentrated into a vast basin-shaped hollow occupying the middle portion of the valley, below the present junction of these three streams, and here the circumstances would be exceptionally favourable for the accumulation of great thickness of ice. The triangular shape of the collecting area above this, and also the convergence of the two valley walls towards the gorge, tended to maintain this thickness for a great length of the course of the ice-stream, since narrowing of the cross section of the valley compensated for losses by melting, ablation, etc., and thus the thickness of the ice could be measured in thousands of feet as it left the mountain tract to debouch on to the plains.

Estimates of thickness can be based only on the presence of traces of ice above the valley floor, but in this case care must be taken to eliminate such evidence as may be due to tributary ice coming from hanging valleys, basins, and hollows in the upper part of the valley wall. The height of the characteristic break in the form of the cross-section of the valley and the occurrence of a definite shelf will give an approximation to the height. This shelf shows perfectly along the southern wall of the valley from Double Hill round the northern flanks of Mount Hutt, as well as on the end of the Big Ben Range. These give a thickness of ice in this portion of the valley of at least 3000 ft. It may be urged that one is not justified in assuming that the ice extended to the top of the facet on the end of the spur, and that the upper portion of the face might be due to frost action or to slip or slump from the undercut termination of the ridge, but the uniformity of the slope and the fact that it is evidently part of one landscape feature from top to bottom, and that the form is the same in so many cases, seems to justify the assumption that the thickness of the ice may be gauged by taking the height of the top of the facet above the floor of the valley. The large masses of greywacke on the top of the rhyolite and andesite of the Rockwood Range at heights of over 1200 ft. above the floor of the valley, and also the smoothed surface of Round Top Hill (2917 ft.) in that range, give a minimum thickness of 1300 ft. to the ice in the Rakaia Valley in close proximity to that range.

There is some doubt as to how far the ice came out on to the plains owing to the difficulty in discriminating between morainic and fluvio-morainic material, especially when both occur in the same place and merge into one another. On the north side of the river the ice certainly came as far as a mile below the line of the road leading to the top of the terrace on its way to the Gorge Bridge, for morainic mounds with large angular blocks occur in irregular dumps about this spot. But below this, about a mile and a-half further down towards Glenroy, there is a wide-sweeping, semi-circular ridge, in form like a terminal moraine with surface irregular mounds, composed of angular stones. Behind this the land is low, and in places swampy, and its form stretches down to the Hororata River. About a mile above the bridge on the main road, on the banks of the Hororata and its tributary, Washpen Creek, there is a tenacious clay, containing angular, sub-angular, and rounded stones, some of the last being definitely striated, and many with suggestions of ice-wearing. The clay generally looks like a boulder clay, but in places it has a texture looser than that of a typical till. Scratched stones are also found on the downs between Washpen Creek and the Hororata River. Lying on the surface are also large angular blocks of rhyolite and occasional greywacke (Photo No. 9). The former are up to 8 ft. in diameter, and are exposed on the terraces and beds of both the main stream and its tributary. Whether these have been included in the clay or represent a surface deposit which the streams have not been able to move along with the finer material is not clear, but no block was seen to be actually embedded. Both the scratched stones and these large blocks indicate the presence of ice on the ground where they occur, and the presence of a boulder-clay indicates an extension beyond the line where the deposit occurs, since it must have been laid down under the ice and not actually at the ice front. The presence of large stranded blocks of rhyolite well out from the foot of the hills west of the Clearview Coal Mine, on the north side of the Hororata (Speight, 1928, pp. 2-3), supports the contention that the ice extended on to the plains, and if so, the fluvio-glacial deposits as distinct from the glacial, and lying on them were laid down during the retreat of the ice from this apparent maximum. Haast (1879, pp. 386-7) considered that the ice reached as far as Woolshed Hill, which forms a ridge on the top of the terrace above the Curiosity Shop, some three miles downstream from the gorge. He said that the hill was composed of angular blocks lying on sand and gravel, and marked the maximum advance of the ice along the line of the river. This conclusion appears quite reasonable, in view of the definite proof of the presence of ice near the Hororata, about the same distance from the gorge and somewhat out of the line of the direct advance of the ice.

The hill was re-examined in order to see if any fresh evidence was forthcoming. It is unfortunate that there are no good exposures either natural or artificial, and the greater part has been ploughed. As far as can be seen, the hill is chiefly composed of rounded and subangular gravel, well cemented, and without scratched stones, nor are the stones of large size. They may belong to the Kowai Gravel series, and may thus be pre-glacial in age, and the height of the ridge may be accounted for as being a remnant of a widespread preglacial covering, not destroyed by the action of ice or rivers. It is possible that they may, after all, be fluvio-glacial, though no precise evidence of ice action was observed in the limited exposures.

The summit of the hill, however, shows deposits of large angular blocks which confirm Haast's conclusions. These form low mounds which have escaped ploughing owing to their roughness, and they give the top of the ridge the characteristic topography exhibited by morainic dumps, where the roughness of the surface has been to some extent modified by a coating of soil. A specially distinctive heap lies a few chains north-west of the trig. Within a circle four yards in radius lie seven angular blocks, rhyolite and greywacke, over 4 ft. in diameter, with one 7 ft. by 5 ft. by 3 ft. These rest on other blocks partly buried in the ground. Their angularity, size, and position negative the possibility that they were deposited by water action. This is not the only accumulation of similar blocks, and masses up to 4 ft. in diameter are quite common, usually in aggregations. So that it is my opinion that while the great majority of the hill is probably of pre-glacial age, ice really came down over it, and left the thin veneer of blocks which forms its highest elevations.

On the south side of the river there is similar evidence. Just past the creamery on the road between the gorge and Methven there are heaps of angular stones, in the form of a crescent, with one horn resting on the flanks of Mount Hutt, and the other on the terrace just where the roads to Mount Somers and Methven diverge (Photo No. 10). There are also, still nearer Methven, a number of mounds which, judging by form, may be glacial in origin, and if so, it may mean that the ice extended within three or four miles of that township, which is not remarkable when one considers the position of the ice-front on the north side of the Rakaia when it reached its furthest.

The ice crossed the Rockwood Range at a height of 1300 ft. above the plain, and the fact that it had probably disappeared by the time the Hororata had been reached near Glenroy appears somewhat strange if the range had existed at its present height at the time of the glaciation, and I have suggested elsewhere (1928, pp. 52-3) that some change in height may have taken place since then, and noted that there is faulting in the gorge which affects post-glacial silts, as well as a definite earthquake rent, which must be of recent date, following along the south-eastern face of Bryant's Knob, and oriented in a N.E.-S.W. direction. There is, however, little direct evidence for this hypothesis, and when one considers the height at which there are now definite evidences of glaciation, and the magnitude of the ice stream which must have existed to produce them, then the traces which we see on the flat are not commensurate with this size, but rather indicate much weaker flows, and therefore it is possible that the ice extended for some distance on to the plains, that the clay near the Hororata is a true boulder clay laid down at the time of the great advance, and that the moraine and fluvio-morainic material, such as that between the Switching Station and the Gorge Road, belong to a period when the ice maximum had long passed, and indicate mere phases in the decline and retreat of the ice streams, or in all probability a fresh advance of less importance.

The general conditions of the mountain basin of the Rakaia at the height of the glaciation must have been as follows:—The great mountain basin was full of ice, fed chiefly by three great streams coming from the main divide down the valleys of the Rakaia, Mathias, and Wilberforce, with a subordinate flow down the Avoca. These streams coalesced and covered the whole country now occupied by the main Rakaia Valley, Lake Coleridge, and the country east of it. Perhaps the tops of such mountains as Oakden (5364 ft.) and Ida (5575 ft.) stood up as nunataks above the ice-field, but the valleys parallel with the lake were so completely flooded that they did not show in any way on the surface of the ice, except in so far as they affected the flow from depth, much as a deep river is affected by irregularities in its bed. After leaving them, the streams coalesced again, moved over the country south of Lake Coleridge, crossed the line of the Acheron, became more or less hemmed in between the end of the Big Ben Range and Mount Hutt, and, as the cross-section of the valley narrowed, passed over Snowdon and Fighting Hill (2393 ft.), over the Rockwood Hills, and reached out as a piedmont as far as the line of the Hororata near Glenroy, on the north side of the river, and in the vicinity of Methven on the south.

The basin was so filled with ice that distributary streams passed over saddles and the lower parts of its bounding ranges. These were:—

1. To Lake Heron and on towards the South Ashburton.
2. Over Redcliffe Gully to the North Ashburton, by way of its tributary, the Swift.
3. Along the northern side of the Big Ben Range, into the basin of Macfarlane's Stream and the Kowhai.
4. Down High Peak Valley and over Middle Saddle, and also into the valley of the Upper Hawkins.

These will be dealt with in turn.

(i) *The Lake Heron Overflow:*

This was perhaps the main distributary from the Rakaia. The evidence for it is to be seen in the ice-scoured slopes on either side of the Lake Heron Valley, as far down as the line of the South Ashburton, but specially near the Rakaia end of the Lake Heron Valley; the semi-detached knob called Prospect Hill and its glaciated and moraine-covered surroundings on the left side of the Lake Stream at its junction with the Rakaia; the ice-scoured basin immediately above the junction; and the large terminal moraine on the southern side of Lake Heron. This is no doubt a recessional feature, just as the moraines near the Rakaia Gorge are recessional, for the ice-smoothed slopes extend for miles beyond the moraine, and at higher and lower levels. Though the Rakaia contributed largely to the stream going through the Lake Heron Valley, it must be remembered that the Cameron and Ashburton Glaciers coming from the south-eastern slopes of Mount Arrowsmith were of great extent. They filled the valleys of the rivers now occupying them, and passed over the slopes between them, and on their own account flooded a large extent of country. The Cameron was no doubt a substantial contributor to the material of the Lake Heron moraine. The width of the valley at the spot is some six miles; it is much narrower towards the Rakaia, but the body of ice coming through it must have been of very considerable dimensions, and materially relieved the pressure in the main valley.

(ii) *Overflow by Redcliffe Gully* (Photo No. 11):

On the top of the limestone outlier of Redcliffe Hill (3060 ft.) and in the valley leading down to the Ashburton, moraine occurs freely, and the ice-scoured slopes both above and below the turn-off from the main valley indicate clearly that a distributary stream of comparatively small size entered the Ashburton River basin by way of this saddle. It is probable, too, that another small distributary crossed by Turton's Saddle (3700 ft.)—which is between Redcliffe Saddle and the Lake Stream, at the head of the Glenrock Stream—into the North Ashburton by way of Turton's Stream.

(iii) *The Benmore Distributary:*

The evidence for this is not so definite, but large greywacke blocks occur resting on coal-measures and volcanics of the Benmore outlier, whose presence can most reasonably be explained by ice transport across the rather low saddle to the south of Porter's Pass, north-west of the Big Ben Range.

(iv) *The High Peak Distributary:*

The High Peak Valley was probably filled with ice, and there was an overflow to the Hawkins, as well as over Middle Saddle (2491 ft.) to the valley of the Upper Hororata, evidenced by large blocks of greywacke resting on andesite at the top of the saddle. These blocks must have come from higher up the Rakaia Valley. This implies that an ice-sheet filled the High Peak Valley and crossed a saddle 1200 ft. above its floor. This contention is, of course, subject to the condition that the range may have risen since the ice maximum, and then such a great thickness of ice in the High Peak Valley would not be required to account for stranded blocks at such a height. However, a great thickness of ice is required to account for the height of the ice-scoured shoulder of Big Ben, on the north-west side of the entrance to the valley. The passage of ice through into the Hawkins basin is indicated by large blocks of greywacke found lying on coal-measures near Russell's Flat (Speight, 1928, p. 3).

3. *Phenomena associated more particularly with Ice Advance:*

The chief phenomena associated with ice advance are those dependent on abrasion. This has left its mark on almost all parts of the area. The most noteworthy are the production of steep lower slopes and the formation of a distinct shelf or shoulder on the valley walls near the upper level of the ice; the narrowing of ridges between adjacent parallel valleys by lateral sapping and abrasion; the triangular facetting of spurs; the formation of semi-detached knobs on the ends of spurs, such as Prospect Hill, at the junction of the Lake Stream and the Rakaia, Mein's Knob, and Jim's Knob, at the head of the Rakaia; the formation of fields of knobs or roches moutonnées at the ends of spurs, such as occur between the Harper and Lake Catherine, on the slopes of Mount Olympus; the cutting down of divides as between the Rakaia and Lake Heron, between the Wilberforce and the Rakaia, in the vicinity of Mount Oakden and Mount Algidus, and the cutting down of the divide between Glenthorne and the Avoca behind Mount Gargarus; and the general production of roches moutonnées in the floors of valleys by abrasion or by scouring and plucking.

This leaves out the question of the efficiency of glaciers in causing valley excavation as distinct from abrasion. At first sight it might be postulated that the form of Lake Coleridge, with its deeply depressed floor, and also the hollow formed in the Rakaia behind the rock barrier at the gorge were both the result of the excavating power of thick ice. This is a matter concerning which there is room for difference of opinion. There is some reason for thinking that the hollow behind the rock barrier at the gorge is in the main structural in origin. This point has been dealt with by the present author in his paper on the Rakaia Silts (1926, pp. 56-7). In support of this it may be pointed out that the general effect of the glaciation appears to be modification of pre-existing landscape forms in this region rather than the creation of radically new ones. The fact that the tributaries of the main valleys of Canterbury which have been subjected to glaciation show no discordance in grade at their junctions with the main streams, supports the contention that the ancient glaciers of this region for some reason or other exerted little excavating power. Although this is the case here, I believe that in other instances glaciers have great powers of excavation.

The origin of the Lake Coleridge basin should also be considered in this connection. The only phenomenon bearing on the question as far as I know that gives any indication of deformation of the basin is the occurrence of drowned valleys near the peninsula on the east side of the lake. This implies either a depression of the land in their vicinity or the raising of the water of the lake relative to the land, and the latter alternative appears to be impossible, since all the evidence points to a lowering in the level of the water, except in so far as the fan of the Harper may be responsible for some slight rise, and this would not account for the amount of drowning exhibited. It is perhaps significant that this evidence is only furnished by the middle of the lake, and also that it is near the line of one of the possible E.N.E.-W.S.W. faults which have affected the area. In other parts of the lake there is no apparent evidence of drowning, but the walls are so steep and regular that such evidence would not be forthcoming. If the drowning be restricted to the middle section of the lake, then it points to a sagging down of the middle of the valley. After all, the required deformation is not great. Assuming that the depth of the lake is 700 ft., then for 5½ miles in either direction from the middle point the grade of the bottom would only be 1 in 40, quite a gentle gradient. If, however, one does not admit the possibility of warping, then it seems impossible to restore the valley in imagination to its condition antecedent to the ice-flood without asking for considerable powers of excavation when the ice is even moderately thick. If one restored the pre-glacial grade of the valley then the thickness of the ice, before it commenced such excavation, granting that there had been no warping, could not have exceeded 3000 ft., and it may not have exceeded 2000 ft. judging from the evidence of the height to which ice reached on neighbouring mountains.

Boulder clay with scratched stones occurs on the western shores of Lake Coleridge in the vicinity of the intake, forming cliffs washed at their base by the lake, and the deposit stretches across the down country to the other end of the supply tunnel, where there are also numerous scratched stones in the deposit. Although it was maintained by Hutton that scratched stones were rare in New Zealand, it is only a matter of looking in the right place and they can nearly always be found. Thus a specially favourable situation is where a glacier climbs out of a deep bed over a rock barrier. This accounts for the occurrence of such stones on the slopes of Fighting Hill, on Sebastopol, in the Mount Cook region, on the St. Bernard Saddle, near Cass, and near the Bealey Hotel in the valley of the Waimakariri, where the Waiau Glacier climbed out of its valley towards Lake Guyon, where the Rangitata climbed the bank near the Potts River at Ross's cutting, and the occurrence here is quite analogous, for the Coleridge Glacier rose from the lake bed over the ridge of greywacke towards the Rakaia River in the direction of the Power House. Scratched stones do occur in other localities, not so placed; for example, near the mouth of the Acheron River, on the downstream side of the rock barrier at Rakaia Gorge, in the High Peak Valley just below the homestead, and the possible case near the junction of Washpen Creek and the Hororata, though in this last case greywacke in position is exposed in close proximity.

Some of the material near the end of the tunnel at the top of the pipe-line, and also that near the intake in the cliffs facing the lake, is hardly tenacious enough for a boulder-clay, being incoherent and floury in texture, and is much more suggestive of surface-till; that is, material contained in the ice and dropped as the ice melted. Some of it, too, is rudely stratified, and contains rounded pebbles, which suggest that it is fluvio-glacial in origin.

4. *Recessional Phenomena:*

Perhaps the most interesting physiographical phenomena of the area are those associated with retreat of the ice. There are first of all the Moraines, either organised into definite land forms or the sporadic blocks scattered on the land surface. The most important areas where these occur in the order of the retreat of the ice are (i) on both sides of the river in the vicinity of the gorge; (ii) on the road leading to the High Peak Valley, between Fighting Hill and the High Peak Station; (iii) on the high banks of the river lying over lake silts, below and above the junction with the Acheron, and upstream towards the Power House; (iv) on the down country on both sides of the road leading from the Acheron to Lake Coleridge and the intake of the tunnel; (v) in the Upper Acheron Valley; (vi) to the east of Lake Coleridge, opposite the peninsula; (vii) to the south of Lake Heron, between the lake and the South Ashburton; (viii) on the downs near Prospect Hill. In addition to these more or less definitely organised deposits, isolated perched blocks may occur almost anywhere. Considering the magnitude of the ice streams which issued from the area, the quantity of moraine must be considered insignificant, nor is there the organisation of the material into definite barriers such as one would be led to expect. But this is characteristic of the river valleys of Canterbury, the only dam-like forms that I am aware of being in the upper valleys of the Clyde and Havelock, tributaries of the Rangitata, and at one place in the Cameron. The whole circumstances of the thickness and distribution of moraine suggest singularly rapid retreat, so that there were few halting stages of sufficient length to allow of definite terminal accumulations, apart from those near the face of the ice at its maximum extension.

The terminal moraine stretching from the Hororata River near its junction with Washpen Creek to Woolshed Hill shows the effect of the attack by streams issuing from a retreating ice-front or a stable front further back. One channel of this river must have followed down the line of the road from the Gorge towards Hororata township, and swept away the moraine from that section. In spite of this and other attendant destruction the remnants are impressive, and indicate a fairly long period when the ice-front was practically stationary or subject to slight oscillations. All the same the size of this moraine, even if restored to what in imagination it must have been originally, is hardly commensurate with the thickness of the ice and the size of the glacier which must have existed at the outlet of the valley only three miles away.

There is a considerable space between this terminal moraine and the morainic hummocks near the road from the Point Station to the Gorge, which does not disclose evidence of the presence of ice. Although the hummocks may not be actually recessional, and indicate renewed advance after retreat, they do not postulate a long period of stability of the ice-front, but somewhat rapid recession from a temporary advance.

The inclusion of moraine among recessional phenomena may seem peculiar, but its deposition is in most cases a phase of retreat, since the material has generally been spilled from the margin of the ice or dropped where it melted. All the same moraine does indicate the presence of ice in a locality once free from it and therefore suggests advance. Even well-defined moraines, such as that just mentioned and those near Lake Heron and on the High Peak Road, indicate a maximum advance closely followed by recession. Ground moraine is more definitely a feature of advance, but it, as well as other advance phenomena, may be features of recession, and vice versa.

When the ice began to retreat from its maximum advance it would naturally evacuate that portion of its occupied territory lying on the plains and in the lower part of the High Peak Valley. Its terminal face would retreat up the valley, but it is probable that the main Rakaia Glacier would occupy ground further down the main valley than the glaciers reached in the parallel valleys to the east. While the main valley would continue to receive substantial contributions from its head near the main divide, and also from the Wilberforce, also reaching back to the divide, the valleys lying to the east not heading so far back would be only partially occupied, and conditions would resemble those now existing at the Tasman and Murchison Glaciers. It appears fairly clear that the lower ends of these valleys would become ice free progressively from the east, that the valley which is the continuation of the Avoca would be free, while the Lake Coleridge valley and to a greater extent the main Rakaia were filled with ice.

It is clear that portions of the area thus uncovered were occupied by lakes, ponded back between the ice-margin and irregularities in the floor, especially if ice invaded the lower portions of the eastern valleys from the main streams occupying the valleys to the west. The existence of lakes is proved by the presence of stratified silts near the point where the Coleridge-Lyndon road climbs the ridge after leaving the Coleridge Creek Valley at a height of some 300 ft. above the level of the lake, and near the intake of the pipe-line from the Acheron. There are also well-developed level terraces on the lower slopes of the Craigieburn Range, in the vicinity of Coleridge Pass, which can well be explained as lake terraces, if a lake formed by the valley were blocked by a solid barrier or by ice, or by a combination of both at its lower end, while the escape of water in the direction of Lake Coleridge was prevented by the side of the glacier filling the gap between the southern end of Cotton's Sheep Range and the northern end of the Kaka Hill ridge.

The following is a description of the landscape features obtaining in this locality. The main part of the area near the road lying between the courses of the Scamander and Simois consists of a level terrace about 175 ft. (aneroid measurement) above present lake level. This extends back from the road for about half a mile, with occasional sink holes and one or two small mounds composed of pebbles and finer material, and rises either directly or with intermediate discontinuous shelves at various levels to another terrace 175 ft. higher. The intermediate shelves are more definitely developed towards the Simois, though one lies on the eastern side of the Lake Georgina Valley. This will be referred to later. Behind this second terrace is a flat area, from which rises another terrace, 350 ft. high (Photo No. 12), with one or two intermediate shelves, and with its top edge bordered with moraine in irregular heaps. Behind this the terrace is horizontal as determined by aneroid and abney level, except for fairly numerous large and occasionally deep sink holes. The surface of the terrace, except for the margin, shows no evidence of moraine, but is composed of finer angular and sub-angular material. At its northern end this terrace extends across the mouth of Moraine

Creek, and is succeeded by a higher terrace, and to the east of this creek by several horizontal shelves. Then for a space it rises gradually to the fan which leads up to Coleridge Pass. Further south the surface is marked with roches moutonnées, and then it rises about 25 ft. to another terrace, edged with a levee of morainic heaps and with a flat surface behind the levee. A remnant of this terrace lies across the entrance to the valley east of Lake Georgina Valley, with roches moutonnées and morainic dumps occupying the entrance and a portion of the upper part of the valley at higher level. East of this again, behind a row of roches moutonnées lies the swampy tract which partly drains to the upper Scamander and partly to the stream running through the deep channel where lie the Red Lakes. Remnants of the main 350 ft. terrace extend along the flanks of Laing's Hill towards the north-west, with morainic heaps above them, the shelves being specially well-developed in the direction of the upper part of the course of the Simois (Photo No. 13). As far as can be determined, the surface of these terraces is as a general run practically horizontal, so they can hardly be river terraces, and they therefore represent deposits in lakes ponded in between the ice-front and the embayment bordered by solid rock to the east and south-east.

When the ice commenced to retreat from the eastern wall, then there would be a discharge along it through the Red Lake Valley and from the front of the ice which reached the upper reaches of the valley west of it. When this valley entrance was freed from ice, and the ice margin retreated from the valley wall further, then moraine would be spilled from its edge, and behind it would lie a lake in which the highest level terrace was formed. Each successive terrace would be formed as the level of the ice lowered, till the discharge would take place through the Lake Georgina Valley. Now the margin of this lake is indicated by the horizontal terrace lying to the east of Lake Georgina, which peters out as a terrace just where the level of the ground in the floor of the valley reaches its highest, the top of the terrace and the summit of the saddle exactly corresponding. Finally, when the gap between Cotton's Sheep Range and Kaka Hill was opened, the lake would drain away and leave the main lowest level terrace free.

Even if it were not occupied by lakes, it is fairly clear that streams would flow along the eastern margin, between the ice and the bounding walls of the valley, as the Murchison River does now, and in this way the gravels and terrace remnants found at fairly high levels, even above the terraces probably formed in lakes, in the more eastern valleys would be accounted for, also the narrow stream channels such as lie at the base of Red Hill, and east of the Acheron in the direction of Snowdon. Some such explanation is necessary to account for these terrace remnants, for they occur at times so high above the floor of the valley that it is unreasonable to think they could have existed while the valley was being eroded below their level had erosion been by rivers in a normal way. Also it seems unreasonable to consider them remnants of former waste-filled valley, and to have been the result of secondary excavation. The channels running parallel to the valleys would be the spillways for such lateral lakes as then existed, and the depth to which some of them are eroded indicates that the conditions favourable to their formation extended over a long period, and that new spillways were uncovered very slowly.

Although some of the smaller and higher terrace remnants were no doubt stream-formed, it appears very doubtful if the major part of the terraces at a lower level can be attributed to this cause; all the same, the evidence that they are lacustrine in origin is largely the fact that they are level, and that they lie in positions not favourable to their formation by stream action. The occurrence of kettle holes as suggested by Flint (1929, pp. 262-3) supports this contention, and it is hard to see why they should exist if the terraces had been formed by streams. Exposures, by which their intimate structure can be observed, are practically non-existent, and there is no visible occurrence in the area between the Simois and Scamander of varved silts. The material of which the main portion of the terraces appears to be constructed is angular and sub-angular gravel, like that forming the present beaches round Lake Coleridge, and it is difficult to discriminate between this and stream-borne material laid down in the deltas of the torrents which issue from the mountain region round the lake, and likewise it is impossible to separate what may have been the beach deposit of former lakes from the material carried in by streams. When the terraces are narrow and horizontal, their form appears to furnish satisfactory explanation of their origin, but when they are half a mile wide it seems difficult to imagine the circumstances which resulted in the deposit of a wide belt of material with a horizontal surface.

The lake which occupied the upper end of the Georgina Valley with the old beach on its eastern shore has a counter-part in the valley in which Lake Selfe now lies (Photo No. 14). Horizontal terraces at three definite levels mark its old shore-line, and its existence can be explained by the water being ponded between a rocky barrier in the present Lake Selfe direction, the bounding rocky walls of the valley, and an ice barrier near the line of the Harper River. The terraces left behind show the kettle holes suggested by Flint as being a characteristic of the deposit between an ice barrier and a rock slope; in fact, the illustration given by him on page 263 might have been drawn from the occurrence here referred to. The terraces at three levels indicate three definite lake levels. In places the hummocky form of the ground suggests that the heaps might be morainic dumps, but in the few exposures where the structure can be seen there is no indication of moraine, rather the stones are rounded. In a quarry alongside the road where the structure is exposed, the lower beds are composed of small angular material, with scratched stones, and the upper are of well-stratified gravels. There is no appearance of varved silts. Above the terrace the hill-sides have been well scoured by ice action.

The present remnant of this lake is called Lake Henrietta, but this is reduced from what it must have been following on the ice retreat. Lake Selfe is apparently ponded between two fans, the southern one coming down and impinging against the end of a rocky spur coming from the western slope of Little Mount Ida, whereas the northern one is aided in forming a barrier by a small fan coming from Mount Ida itself. The lake appears to be deep along the eastern rocky margin.

There is evidence of an overflow of ice in an easterly direction from the Wilberforce Valley behind Mount Gargarus towards the Avoca Valley, which implies a deficiency of ice in the lower end of that valley while the Wilberforce was still strongly occupied. There is also evidence of an overflow over the saddle between Mount Ida and Little Mount Ida in the direction of Lake Ida, also implying a deficiency in that direction. The peculiar feature on the southern end of the Cotton Sheep Range, called the "Carriage Drive," may also be due to a similar cause. This is a shelf formed of angular material, in places half a chain wide, which swings round the end of the range, getting lower as it is followed north away from the lake, and exhibiting a perfect grade just as a road would when passing up and round the shoulder of a hill. As it approaches the Glenthorne road it gets lower and less and less distinct, and it finally disappears. I have considered it as possibly due to the presence of an earthquake rent, but there is no sign of this on the stabilised fans to the north, or on the solid hill-side further on, so I think that possibility should be ruled out. The most reasonable explanation appears to be that it was the lateral moraine of a glacier which invaded the valley to the east when it was clear of ice while the Lake Coleridge valley was still filled, and that the material spilled over from the side of the distributary glacier, as it does when a glacier reaches the broader part of the valley, or when it debouches on to a plain or other wide area where the ice can spread. Similar landscape forms, but not so pronounced, can be seen in similar positions and due to this cause in the valley of the Upper Ashburton.

All these features point to the eastern margin of the area having been evacuated by the ice first of all, and that there was a progressive retreat allowing lakes to be ponded between the ice and any solid barriers in the topography, and to be progressively drained as new outlets were uncovered.

This method of retreat of the ice is dependent, in my opinion, on the failure of the ice supply on the eastern side of the basin, while it was maintained on the western owing to the greater length of the divide being drained by the western ice streams; but apart from that there is the possibility that the mode of retreat of the ice as a whole, and specially of the larger streams such as occupied the main Rakaia and Wilberforce valleys, was by wastage from the side, and the consequent disappearance of the ice from long sections of the valley simultaneously. This was suggested by the author in a paper on the Lake Tekapo district (1921, p. 40), and the matter has been most fully discussed by R. F. Flint in various papers, but specially in that entitled "The Stagnation and Dissipation of the Last Ice Sheet" (1929, pp. 236-289), where the features resulting from ice retreat in New England are considered in the light of the hypothesis that the retreat took place by gradual wastage from the sides, and not by the orderly retreat of a front up a valley.

It is possible that some of the silts in the lower part of the Rakaia Valley may have been formed in lakes along the margins of the glacier, though this does not appear probable, but the distribution of the moraine in the valley as a thin veneer over certain areas, and its rare organisation into well-defined barriers points to a sudden melting of the ice and the dropping of its load at the point where the debris chanced to lie on the surface of the glacier.

Another recessional feature is the 60 ft. terrace mentioned previously which follows round the shore of the lake. This may be explained by supposing that the ice located on the site of the lake acted as a barrier at the Harper end, elsewhere the lake would be rock-bound, with the possible exception of that part occupied by till deposits just north of the intake of the tunnel. No doubt the ice would retreat from the lake area towards the Harper as the intensity of the glaciation waned, and the barrier would be effective till the ice-front retreated across the line of the Harper owing to the steep, rocky sides of Mount Oakden and the Sheep Range bounding the lake on either side. The overflow of the lake would then desert the channel at the southern end leading to the Acheron and discharge by the Lake Stream to the Harper, and by that river to the Wilberforce. If perchance the glacier again advanced down the Wilberforce across the line of the Harper it would block the gap between the northern end of Mount Oakden and the Sheep Range, and restore the old direction of drainage to the Acheron.

The northern end of Lake Coleridge is now blocked by the fan of the Harper River which lies across the end of the lake, and formerly the Wilberforce may have contributed its quota to the barrier. It is possible that this may have raised the level of the lake beyond the height it reached at the time the ice barrier retreated past the line of the Harper, and this rise may account for the drowning of a portion of the shoreline near the Peninsula mentioned previously, though the rise has not been sufficient to overtake the level of the 60 ft. terrace round the lake.

As long as the ice filled the Rakaia Valley near Double Hill it is reasonable to think that the Cameron and the stream from the ice-front in the Lake Heron Valley would discharge towards the Ashburton, but when the ice retreated upstream from the junction of the Lake Stream with the Rakaia a change in direction would take place. It is possible that it took place slightly earlier, and that the stream from the Lake Heron Valley followed for some distance along the side of the Rakaia Glacier as the Murchison follows along the side of the Tasman. At one time Lake Heron was of much greater extent, and stretched from the great moraine south of it to about five miles from the Rakaia, its bed in that direction being occupied at the present time by a great swamp. The lake may at one stage have been ponded back by the distributary glacier from the Rakaia, which caused and maintained the level at that of the outlet through the moraine to the Ashburton, but when the junction of the Lake Stream with the Rakaia was uncovered, a reversal certainly took place, aided by the steep gradient of the stream channel to the main Rakaia; it falls a height of 260 ft. in five miles.

An important phase of the retreat of the ice was the existence of a lake which occupied the lower part of the mountain valley of the river. The mode of formation of the hollow occupied by the lake and the nature and characteristics of the deposits laid down in it have been fully dealt with by the present author (Speight, 1926, pp. 57-81), and as far as is known there is nothing further to record, though the circumstances of the deposition of the silts and the light they throw on any time record are worthy of much more extended examination.*

An important feature of the glacial history of the region is the evidence of at least three periods of ice advance and three of retreat. These are disclosed in the sections in Pipe-Clay Gully and elsewhere (Speight, 1926). The general order of the deposits resting on greywacke unconformably is as follows:—

1. Moraine.
2. Varved silts, usually grey in colour.
3. Boulder clay with large blocks and scratched stones in a matrix partly derived from No. 2.
4. Varved silts, passing up into coarser silts and gravels, rudely interstratified at the top.
5. Moraine.

Nos. 1, 3, and 5 indicate the presence of ice in the locality, while Nos. 2 and 4 indicate its absence. The amount of advance and retreat in each case cannot be determined, because it is impossible to assign the beds belonging to No. 3 in other occurrences of the silts to the same definite epoch. This is due to the absence of continuity in the deposits, and the possibility that a boulder clay in one occurrence may belong to a different time from that of a similar boulder clay in another occurrence, but still interstratified in the silts. This makes it possible that there are more than three periods of advance.†

However, in view of the difficulty of correlation, it may be true that changes of front indicated by these features may be due to seasonal variations or to variations of short period which imply no serious alterations in climate, and therefore no marked advance of the ice over previous deposits, rather the mere encroachment of the fringe on to deposits laid down in front of it. If this is not the case and the advance has been considerable, then the question may be asked as to how ice can have eroded a hollow like that lying behind the rock-barrier at the gorge and yet have passed over incoherent beds for a considerable distance without seriously disturbing them. Granting that glaciers can erode as well as abrade, as has been proved by F. Matthes (1930) in his account of the history of the Yosemite Valley, then the only way to account for the discrepancy in the two cases is to postulate that the maximum glaciation was a much more serious affair than the late advances, and that while 2000 ft. or more of ice could deepen such a hollow, the thin ice of the later episode was incompetent to perform any erosive work. The general evidence elsewhere supports the contention that the last advance was a much less serious phenomenon than the first.

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* It is most satisfactory to note that at the present time (October-November, 1933) Dr C. C. Caldenius, of Stockholm University, is engaged on the complete examination of these silts, and specially those in Pipeclay Gully.

† Dr Caldenius suggests that Nos. 3 and 4 are part of the same phase, and that 4 represents older silts which have been disturbed and had their structure partly destroyed by the advancing ice. They therefore represent the upper less coherent portion of the till or boulder clay of No. 3. This would therefore reduce by one the number of periods of retreat and likewise the number of advances as suggested by this section.

A final recessional feature is the suite of terraces, both fluvio-glacial and fluvial, which characterise the valley especially in the neighbourhood of the gorge. As the gorge is probably post-glacial as regards the time of cutting, the terraces which flank it on either bank are no doubt fluvial, while those at higher levels between it and Round Top on the one hand and between it and the foot of Mount Hutt on the other are dominantly fluvio-glacial. No doubt the two forms grade into one another, just as the fluvio-glacial grades into the morainic, and it is at times difficult to distinguish them. Higher up the valley, what are apparently fluvial terraces may, after all, be marginal lake beaches, and vice versa. They also are difficult to classify at times.

5. *Comparison with other Glaciated Valleys.*

A somewhat interesting comparison may be made between this exposed glaciated valley and a drowned valley or fiord. A comparison with Milford Sound or George Sound does not bring out any striking points of resemblance, but this is not the case if the Rakaia Valley be compared with Dusky Sound, and especially its upper portion. If the former were submerged till the sea was 100 fathoms deep over the general floor of the valley between Round Top and Mount Hutt, then the two would be almost exactly identical. The threshold so characteristic of the mouths of fiords would mark the entrance to the flooded area, the water would be deep inside this and carry its depth far into the mountain tract, the alignment of the islands with their cross passages so formed in the Rakaia would be analogous to those of Dusky, as well as the parallelism of the rows of islands, and there would be the drowned Lake Heron Valley to correspond with the Acheron Passage in some particulars, but not in depth. The similarity would be so remarkable that it could hardly be the result of chance.

The interpretation of the origin of the features of the Rakaia Valley as given previously in this paper is somewhat in favour of Gregory's hypothesis that fiords are determined by the fracturing of a plateau land. All I can say in this connection is that I think the Rakaia Valley and its system of parallel valleys may be structural in origin, that they were in existence before the glaciation, and that their form has been modified by glaciation, and perhaps this sequence of events could be applied to Dusky Sound by way of explaining its peculiar features. It is probable that the hollow occupied by the lower reach of the Rakaia glacier and subsequently the site of a lake is structural in origin, but has been modified, and probably deepened when the ice was thick at the peak of the ice-flood.

As far as the other valleys of Canterbury are concerned it may be pointed out that the Waimakariri and Rangitata have features analogous to those of the Rakaia, and the former is certainly, and the latter probably a structural basin. The uppermost reach of the Ashburton valley is a U-shaped hollow with a rock bar at its lower end, now notched by the stream, and the Potts Valley parallel to it and lying to the west has a similar form, and in the case of the latter its structural origin is supported by the presence of an outlier of coal-measures within the hollow, while to the east of the Ashburton is the valley of the Cameron, apparently in a similar position, but without any barrier whatsoever, the valley being open at its lower end. The Mackenzie Country, too, furnishes definite evidence that it is a great structural basin, but the lakes occupying the valleys which extend into the heart of the Mount Cook region are shallow as compared with those of the west of Otago. Solid rock is not apparent at the lower end of Lake Pukaki, the ponding being apparently chiefly by moraine, whereas in the case of Lake Tekapo the solid rock shows in close proximity to the outlet, though the upper levels of the lake are ponded back behind a barrier of moraine; this, however, is in all probability only a thin veneer. Thus in that part of the Alps where glaciation must have been most intense, and the deepest hollows due to glacial erosion should occur, if glaciers are always competent excavators as distinct from abradors, there is no clear evidence of a marked threshold and of a deep hollow behind it.

E.—CAUSE OF THE GLACIATION.

In concluding this account of the glacial phenomena of the region, some allusion should be made as to the probable cause of the glaciation. Three explanations have been advanced to account for it. These are as follows:—(i) That the mountains were more plateau-like in Pleistocene times, and held more snow in consequence of their thus furnishing larger collecting grounds; (ii) the land was higher, and therefore the glaciers came down further before they melted; and (iii) there was a refrigeration of the climate without any marked change in level.

The first of these hypotheses was advanced by Haast (1879, pp. 372, et seq.), and he appears to have been the only authority who held this opinion. The evidence from the Rakaia Valley is against this, since the valley directions and also their forms were determined before the onset on the ice, and there does not appear to have been any pronounced modification of their landscape features by the ice. The ice has been merely an abrading agent, and there is no evidence that the area had any decided plateau-like form.

The second hypothesis has been most favoured, and it is supported by Hutton, Park, Marshall, and others. While admitting that there is evidence that the land was higher than at present, it is difficult to say definitely whether or not this was synchronous with the ice advance and the actual cause of it. There is evidence that other countries in the southern hemisphere experienced a similar increased glaciation; mention need only be made of Tasmania, South-eastern Australia, South America, Kerguelen Land in order to show how widespread was the glacial advance. It is unreasonable to explain all these cases in the same way, since the advance occurred in Polar regions, in temperate regions, and in the tropical regions of the Andes. It would thus demand a change in level almost hemispherical in its incidence. This, of course, could easily be explained if it were possible to attribute the apparent higher level of the land to a world-wide sinking of ocean level. According to "Daly's Theory of Glacial Control for the Formation of Coral Reefs," while a lowering of sea-level occurred in the tropics during glacial times, a rise in level of the sea occurred in latitudes higher than 45°. So the increased glaciation could not be attributed to a cause dependent on the eustatic change in level of the sea in accordance with Daly's hypothesis. It can hardly be the case that the phenomenon is in one case the cause and in the other case the result of change in level.

According to Antevs (1928, p. 81), and basing his calculations on estimates of the volumes of the ice-sheets in Pleistocene times, the lowering of the level of the sea by abstraction of the water and locking it up in the form of ice could only have been responsible for lowering the surface of the sea on both sides of the equator by 305 ft., if the glaciations in both hemispheres were simultaneous, and if the contemporaneity was only partial the sea-level may at most have been lowered 290 ft. This amount of lowering would be increased in the tropics and diminished in higher latitudes owing to the attraction of the mass of ice located near the poles, and in sub-polar latitudes there would probably be a raising of the surface of the sea, an effect which would gradually diminish in temperate latitudes. It is thus possible that little change in level from this cause could occur in New Zealand, and therefore it would be incompetent to account for the advance of the ice in that country.

The only evidence that the Rakaia furnishes in this connection is that arising from a consideration of the height of the terraces. These are highest at the base of the mountains near the gorge, and become progressively lower when traced towards the sea. It is most convenient to explain this as arising from differential elevation of the land along an axis parallel with and practically coincident with the base of the mountains. The same evidence is furnished by other Canterbury Rivers, such as the Ashley, Waimakariri, and Rangitata, but doubtfully so in the case of the Ashburton. This elevation must have been post-glacial, for the rivers as they issued from the ice-front were level with the upper surface of the plains, or practically so. Therefore this line of evidence apparently furnishes nothing conclusive. I have also urged (1908, pp. 16-43) the importance of the effect of varying load of waste on the profile of these streams.

There remains the last of these hypotheses to consider, and it presents serious difficulties. Hutton maintained from biological considerations that there was no evidence of more serious refrigeration of the climate than occurs now since the close of the Tertiary era, and it is very hard to controvert his hypothesis. It must be noted, however, that Hutton always placed the date of the glacier advance in the Lower Pliocene; that is, much earlier than suggested by any other authority, a conclusion based on a chain of arguments, and fallacious if one link proves unsound.

Botanists such as Cockayne (see " Vegetation of New Zealand, 1928 ") have accepted an increased height of the land during the Pleistocene as the most plausible explanation of the xerophytic character of the plants inhabiting the Canterbury area, for such increment in height would allow of a more pronounced steppe-like condition existing on the eastern side of the range, and also allow for the development of even more pronounced xerophytic characters than the plants at present show. This is in accordance with the opinion expressed by Diels. Also the distribution of such sub-tropical plants as the nikau *(Rhopalostylis sapida)* and the ngaio *(Myoporum laetum)* cannot easily be explained in any way except by postulating a continuation of mild climate conditions since Pleistocene times. This specially applies to the coastal vegetation. Cockayne says (loc. cit., p. 109, footnote) : " Hardly any of the coastal trees can tolerate more than a few degrees of frost, and when it is remembered that nearly all the genera are palaeotropic, while six species of the coastal forest extend to countries warmer than New Zealand, it seems highly probable that the coastal tree-florula is but a remnant of one much larger, and that the species frequent the shore-line rather on account of the mild maritime climate than through possessing special ' adaptations.' On the other hand, the almost frostless climate of the West Coast of the South Island is not unsuited for some of the coastal trees unless the colder summers and excessive rainfall are antagonistic. Perhaps the absence in the Western District of these species extending to the North-western may be ascribed to the re-populating by plants of the Westland coastal plain after the glacial period." Again, on page 425, he says: " Towards the end of the period of elevation in the Pleistocene, when the mountains were at their highest, came the extension of the glaciers. Then would the palaeotropic element be driven northwards and perhaps eastwards, especially as it is more than probable the glacial advance was, in part, the result of a colder climate. East of the Southern Alps there would be a steppe climate on the plateau." Further on he says: " Towards the close of the Pleistocene, depression of the land set in once more, the glaciers retreated into the mountains, and the re-peopling of the glaciated land as already described began." It is clear that while Cockayne contemplated elevation of the land as being the prime factor in accounting for certain peculiarities of plant distribution, he was quite aware that a change of climate might have taken place, reinforcing the effects of increased height of the land.

Alone among geologists Henderson has maintained that the advance of the ice was associated with a lower level of the land, although his statement is not quite definite. He says (1924, p. 580): " The land was at one time 1000 ft. or more higher than it is now, but later was depressed till the old strand line was submerged to 1000 ft. or more below the present level. The deposits formed prior to and during this depression are here considered as Early Pleistocene, and those of the succeeding elevation of younger Pleistocene age. The former deposits are represented by volcanic accumulations and by beds of glacial fluviatile, estuarine, and littoral origin." The sentence does not make it clear whether the glacial deposits are associated with the prior elevation or the later depression, though it is understood that it is with the latter that Dr Henderson associates the glaciation. The evidence on which these conclusions as to the changing height of the land and the time of the changes, as well as the reasons for the association of the former period with glaciation, are not given. In the paper just cited, Henderson evidently believes that the changes in level of the strand-line were due to changes in sea-level or that New Zealand has moved as a whole, whether the movement be upward or downward, and that " any differential movements between adjacent earth-blocks that may have taken place during these periods must have been small if compared to the plateau-forming movements by which New Zealand has been uplifted as a unit " (p. 591).

In his recent paper on the " Marine Terraces of the North-eastern Portion of the South Island " (1928, pp. 508-56), Jobberns describes the movements of uplift which have affected this portion of the coast-line, and would extend this movement to the coast-line of Middle Canterbury. I have attempted to show (1930, pp. 164-7) that the recent major movements of this portion of the land area have been downward, although I am entirely in agreement with Jobberns's contention as to the coast-line further north. I can therefore see no evidence of eustatic change, or that the land has been raised as a whole. It may be that both eustatic and diastrophic movements have taken place simultaneously, in which case the separation of the evidence indicating one or other may be very difficult. In any case these marine terraces indicate an uplift of the land relative to the sea for a portion of the north part of the South Island, but their precise date has not yet been determined with certainty, so that no correlation can be definitely made between them and the glaciation. Perhaps there is no relation at all, and they are all definitely posterior to the period of maximum glaciation. If they are of Pleistocene age they would tend to support Henderson's contention as regards the northern portion of the South Island, that the glaciation took place during a period when the land was lower.

However, if his contention is correct, and the glaciation was associated with a period of land depression, then the extension of the ice can only be explained by a refrigeration of the climate, and it is necessary to determine if the features of the vegetation as demonstrated by Cockayne can be explained on the assumption that there was no elevation of the land beyond what exists at present, and that the country experienced such a refrigeration that as a consequence ice filled the West Coast Sounds, and that glaciers extended from the central section of the Southern Alps over the plains of Westland beyond the present coast-line, and this at a time when the land was considerably lower in level. The former extension of the ice in that direction is clearly evidenced by the moraines in the sea near Abut Head as recorded by Haast, and if, as Henderson demands, the land was lower than at present, the ice must have extended into sea at least 100 fathoms deep, and perhaps much more.

I think it quite conceivable that the xerophylly of the plants is explicable on the assumption that the height of the land was somewhere about the same level as at present, providing that refrigeration took place, but it appears difficult to account for it were the land considerably lower. The conditions would then approach those of Stewart Island or of the Auckland Islands, or of other sub-antarctic islands whose vegetation shows no evidence of xerophylly. It must be remembered all the same that the height of the mountains has been reduced by erosion since the time of the ice maximum, so that they were probably not much different in height from what they are now even allowing for the sea to have risen as postulated by Henderson. Increased cold would bring about increasedly arid conditions on the eastern side of the Alps owing to diminished evaporation from the seas to the west. It seems possible, therefore, that cold alone would account for the xerophytic character of the vegetation on their eastern slopes. Can the distribution of the shore vegetation be explained as well?

The only way that this seems possible is that during the ice age the tender plants migrated north, and that after the climate improved a southerly migration took place, specially along the shore-line, and that on modified colder conditions obtaining again as at the present time, the warmth-loving plants only survived in sheltered spots such as on Banks Peninsula and in Southern Otago.

The following quotation from a letter to me from Dr Cockayne seems entirely apposite in this connection, and I have his permission to use it. "This brings me to the behaviour of certain indigenous plants in Wellington during this exceptionally frosty winter (1931). Thus everywhere the leaves of the Black-Tree fern have been killed, and in many places the Ngaio *(Myoporum laetum)* has been injured. This is one more hint—if such were needed—of the slight frost tolerating capacity of New Zealand plants in general. Such behaviour is certainly no new thing, and it does look as if they had never been subjected to any really strong degree of frost, and also that the winter temperature of New Zealand had been in the past warmer than colder. Of course, I am not so foolish as to base these remarks on this season's Wellington climate, but it is rather on the knowledge of how our plants have responded to several severe winters in Otago, Canterbury, and other areas; as also as to what has befallen them in countries colder in winter than New Zealand. The difficult question also arises as to how long a period a species would remain 'unacclimatised.' Could a tropical species remain frost shy for millions of years? Or, on the other hand, is the process of increasing toleration of a lower temperature comparatively rapid?

Or, again, has climate any power in regard to altering the physiological capabilities of living organisms? The truth seems to be that science is still profoundly ignorant regarding not only the causes of evolution itself, but of its more debatable side issues. All the above is, as you know, brought forward here in regard to any theories concerning glacial climates.''

An opinion such as this, coming from a distinguished authority like Dr Cockayne, who knows the conditions of the New Zealand plants in field better than anyone, indicates how little reliance must be placed at present on any theory of glaciation for the Pleistocene of New Zealand, based on inferences drawn from the plant covering, and specially on any theory based on climatic change in connection therewith.

It has been suggested that a change in direction of ocean currents might have been responsible for the conditions which caused glaciation. To be a satisfactory explanation it would have to account for the glacial conditions in all lands round the South Pole, at approximately the same time, leaving out of consideration the question of the glaciation of the northern hemisphere, also probably contemporaneously, and, further, a probable worldwide glaciation affecting even the tropics. It is conceivable that a change in the currents in the Southern Ocean might cause a variation in the climate of different lands independently. For example, if the sea bottom to the south and south-west of New Zealand were raised, and the space of open sea reduced till it approximated in width to that south of South America, then the conditions obtaining in South America would exist in New Zealand, and glaciers might again come down to sea-level in the southern part of the country, as they do now in the Chilean Fiords, but such an elevation of the crust, unless it were restricted to the area south of New Zealand, would of itself cause an advance of the glaciers, apart from any effect produced by the deflection of the cold Antarctic current from its present course against our western coast. In this case the biological difficulties mentioned above would arise, so that the problem would again present serious perplexities. However, to sum up the position, in my opinion some change in climate seems necessary to account for the glaciation, and the biological difficulties will ultimately be resolved on the assumption that change in climate did really take place.

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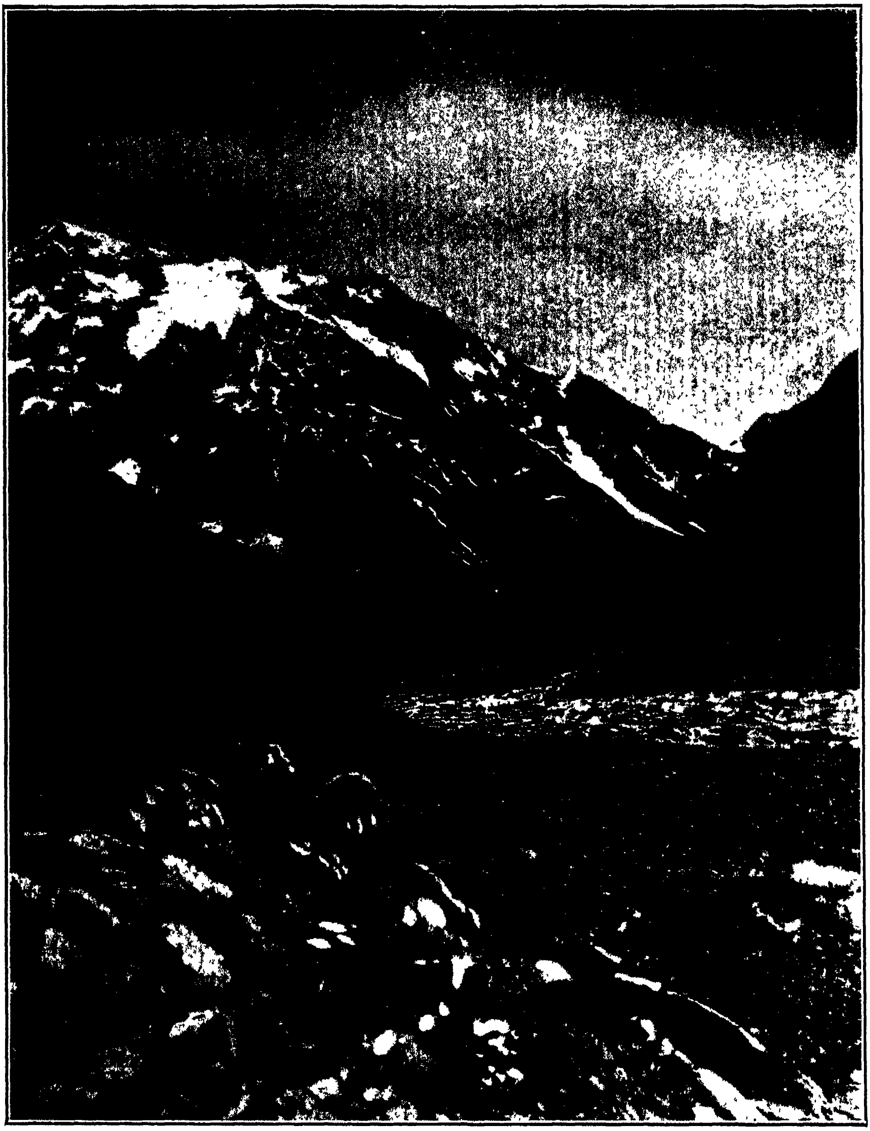

PHOTO No. 1.—Terminal face of Ramsay Glacier, with slopes of Mein's Knob on left. Mount Ramsay in background, and Jim's Knob on left.

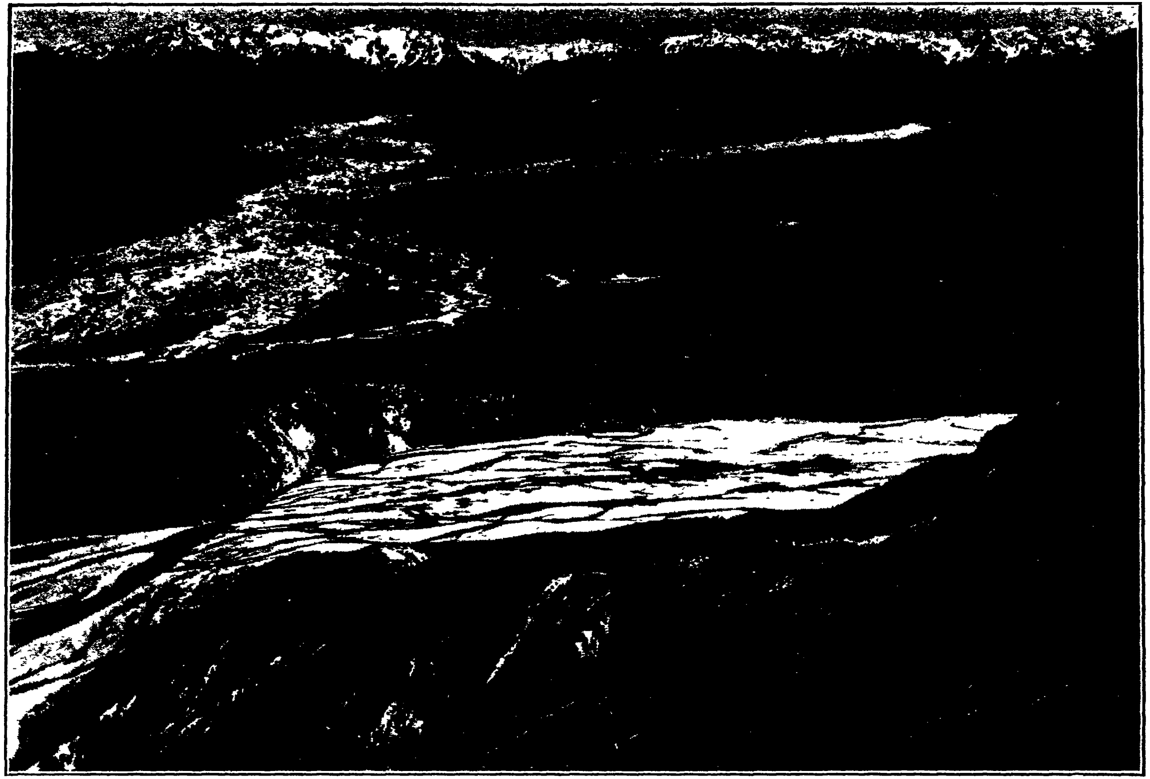

PHOTO No. 2.—Looking up Rakaia River from slopes of Mount Oakden, Wilberforce River in foreground. Woolshed Hill and Algidus Station in right middle; the Mathias River coming in on right distance; Mount Arrowsmith in the background.

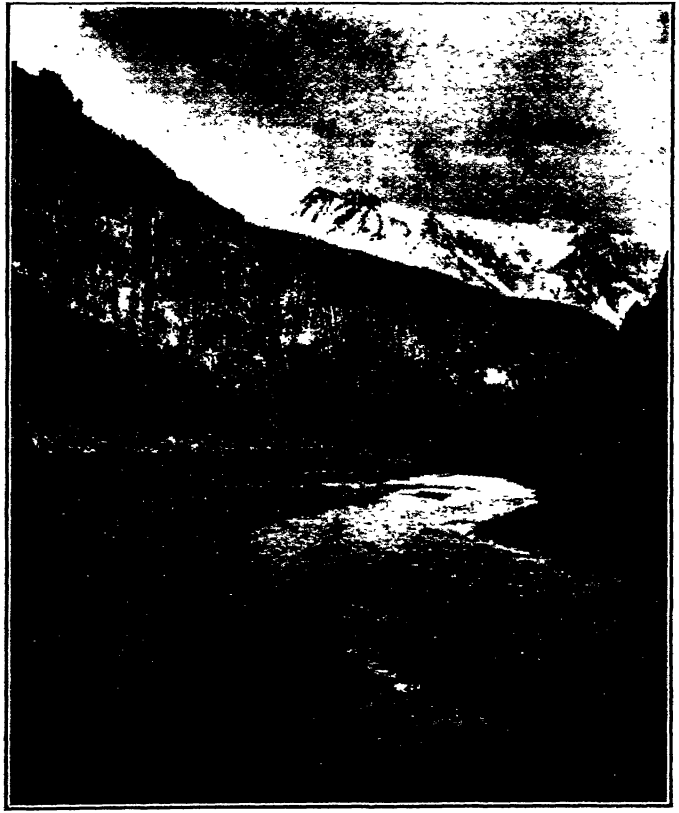

PHOTO No. 3.—Gorge of the Rakaia River; the cliffs are formed of rhyolite.

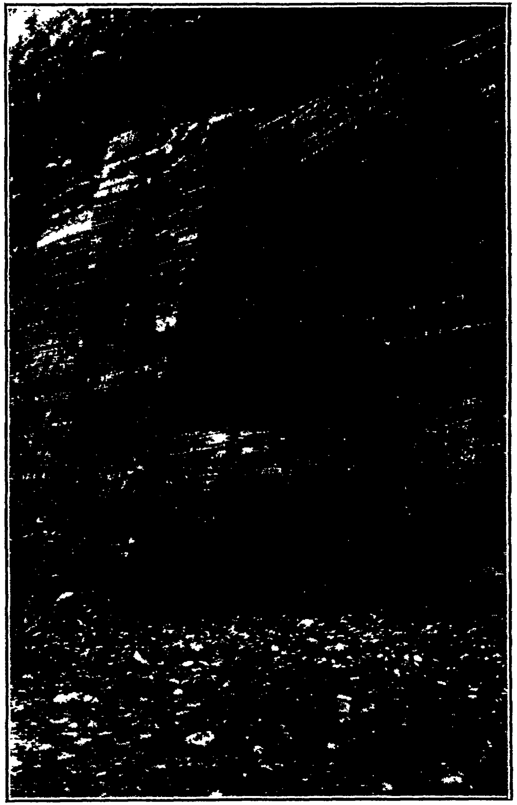

PHOTO No. 4.—Faulted varved silts on road cutting in the Rakaia Gorge, south side of river.

PHOTO No. 5.—Showing bed of Harper River with the Wilberforce beyond.

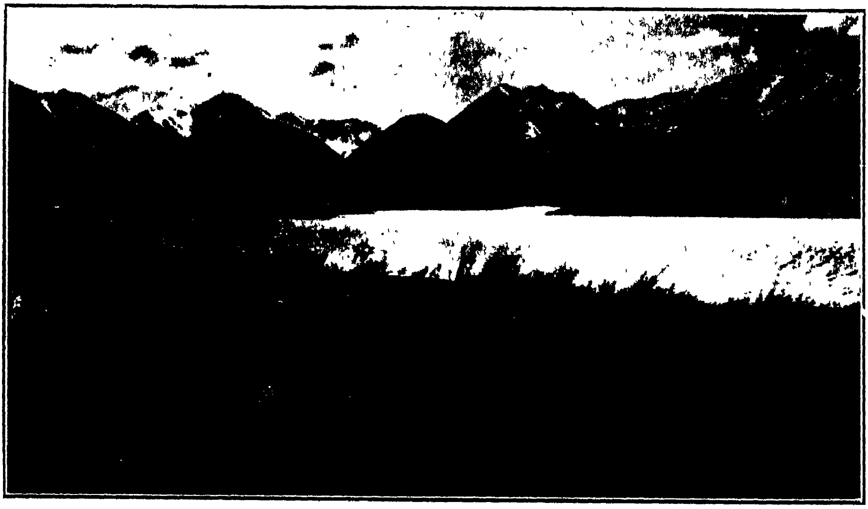

PHOTO No. 6.—Lake Coleridge from just above the intake, showing Peninsula with lake terrace, and rounded hills in the background.

PHOTO No. 7.—Old spit on which the vegetation has been drowned, and new spit formed when the level of Lake Coleridge was artificially raised, but now exposed when the lake has been lowered in winter as the result of drawing off the water for power purposes faster than it runs in.

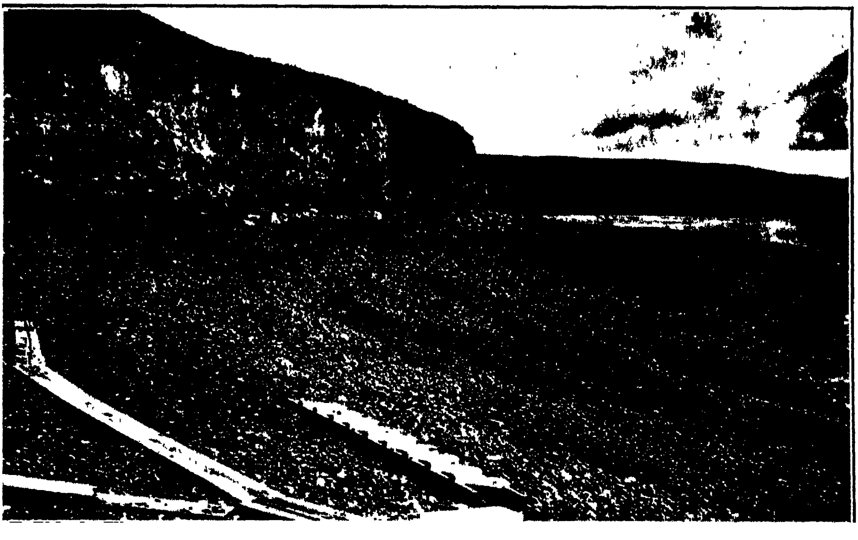

PHOTO No. 8.—Cliffs formed of glacial debris with scratched stones on shore of Lake Coleridge west of the intake, with pebble beach at the base, exposed during low level of the lake.

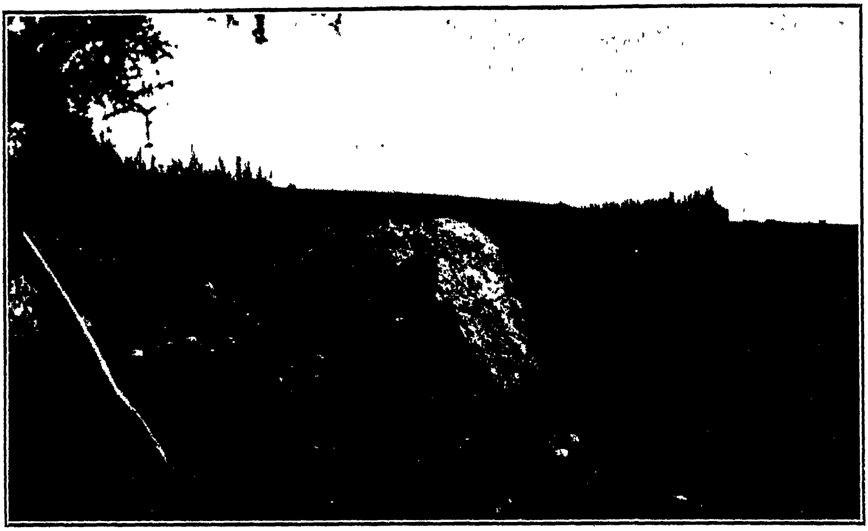

Photo No. 9.—Perched block lying on boulder clay with scratched stones on banks of Washpen Creek, near Glenroy.

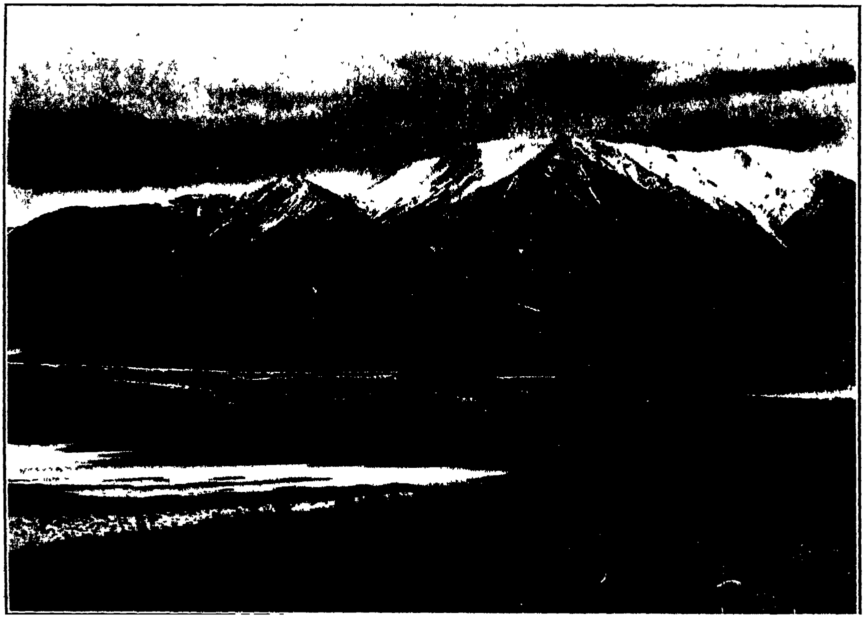

Photo No. 10.—Morainic dumps between the Rakaia Gorge and the foot of Mount Hutt, south side of the River.

PHOTO No. 11.—Redcliffe Gully, showing channel of overflow from the Rakaia towards the North Ashburton. Limestone and other Tertiary beds are exposed on the level of the top of the pass facing the Rakaia.

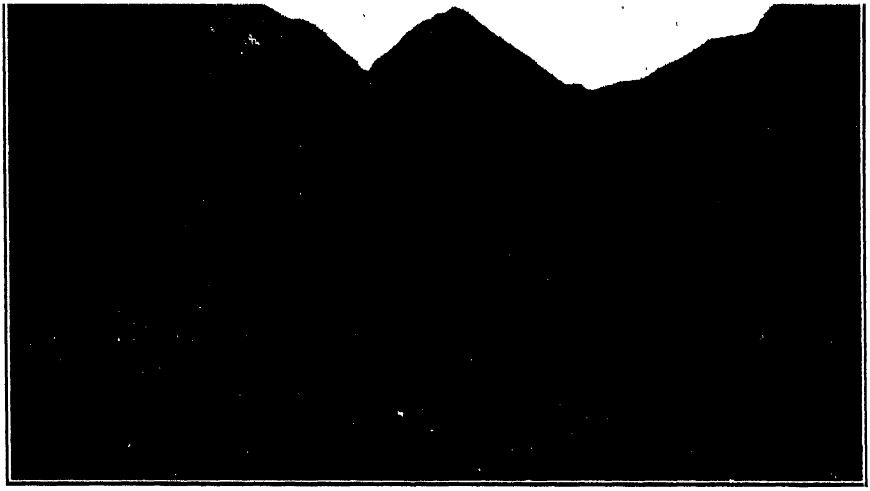

PHOTO No. 12.—Horizontal terraces at head of Scamander Stream. The Red Lakes lie to the left of conical hill in middle distance; Mount Georgina on the left with open valley between them; sink-hole in foreground and roches moutonnées on the left top corner lying at base of the Red Hill. The edge of the main terrace and the heaps to the right are moraine.

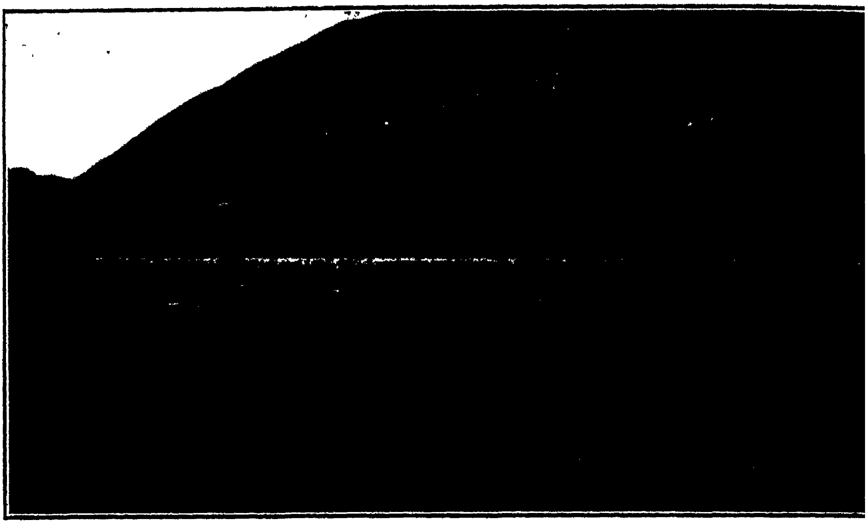

PHOTO No. 13.—Suite of terraces at the foot of Laing's Hill; the Simois Stream lies on the extreme right.

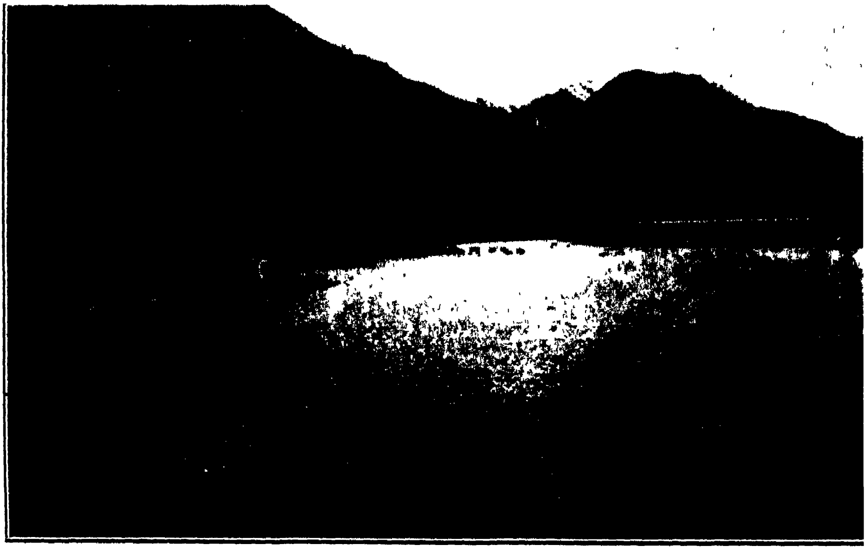

PHOTO No. 14.—Lake Henrietta, showing old lake beach, with ice-scoured slopes of Mount Ida above. Little Mount Ida in the distance. Over the saddle lies Lake Ida. An exactly analogous old lake beach lies similarly placed as regards Lake Georgina.

The Variability and Growth of the Scales of Brown Trout (Salmo trutta) in New Zealand.

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SECTION I.—INTRODUCTION.

SINCE the works of Hoffbauer were published in 1899, many investigators have found it possible to determine, presumably with a fair degree of accuracy, the age of many species of fish by an examination of their scales. The practice has become an important branch of fishery research, especially during the past fifteen years, in all countries that are carrying out extensive research into their freshwater and marine fisheries.

The soundness of the scale method depends upon the validity of certain fundamental assumptions, which may be stated as follows:

(1) That the scales remain constant in number, and retain their identity throughout the life of the fish.

(2) That corresponding to a given increment in the length of the fish there is a corresponding increment in the scales, and that this relative rate of growth of the scales to that taking place in the fish remains constant from the time when the first circulus is laid down throughout the life of the fish.

(3) That the bands of narrow and broad circuli are formed at approximately the same time every year (or that some other discoverable relationship exists between their formation and increment of time).

Incidentally other questions are raised, but the validity of the scale method of computation is not affected by them. They are given by Van Oosten (1929) as follows:—

(1) "Do the annuli represent periods of retarded or arrested growth of the scales?"

(2) "Is the growth of the fish in length retarded or arrested at the time of formation of the annuli?"

(3) "What factors are responsible for the arrest of or retardation of growth in the fish and scales?"

As the life-history of different species, and even different individuals of the same species, varies considerably in the more important details, under different conditions, it is obviously essential that the questions outlined above should be carefully investigated before we can be certain of the validity of the methods we are employing. We are not justified in assuming that that which occurs in one species will occur in another species, even under similar conditions, or for the same species under different conditions, as has previously been assumed in many cases. Before the application of the scale method for the elucidation of the age, growth, and life-history of a particular species is justified, certain preliminary investigations must be carried out. The study of the age and growth of fishes is of a statistical nature. We are not concerned actually with the age and growth of any particular individual. What does concern us is the average age and growth of certain restricted fish populations, or a particular section of such a population. It is of the greatest importance to give in quantitative expressions variations occurring in their average age and growth-rate over a fairly long period of time, tracing, as it were, certain definite sections of a fish population from birth to maturity, and noting any changes occurring, as measured from previous observations. As the methods are purely statistical in nature, the accuracy of the results depends upon the adequacy of the material upon which the results are based. These methods tend to assume the form of vital statistics.

Data are presented, in the present paper, to test the validity of the scale method, as applied to brown trout in New Zealand.

SECTION II.—COLLECTION OF THE MATERIAL.

The localities from which material has been obtained for use in the present study are as follows:—

(a) North Island (1) Dannevirke (Tamaki River).
(2) At various places along the Manawatu River.
(b) South Island (3) Selwyn River, Canterbury.
(4) Aparima River, Southland.

Some of the material was obtained during 1928 and 1929, although approximately 85% was obtained during 1930 and 1931.

The following list gives the number of fish in each of the samples:

402 fish from Dannevirke (Tamaki River) obtained during May and June, 1931.

35 specimens from various localities along the Manawatu River taken during 1930-31.

106 fish taken from the Lower Selwyn River at various dates during 1928, 1929, and 1930.

32 specimens from the Aparima River.

405 fry from the North Canterbury Acclimatisation Society's hatchery at Christchurch.

115 comprising five odd samples, of about 20 to 25 individuals in each.

The total number of specimens examined in connection with the present study was approximately 1085.

The fish taken during May and June from the Tamaki River, together with smaller samples from the Lower Selwyn River and

Aparima River, form the basis of the relative rates of growth of scales and fish. This group of fish, comprising 931 individuals, is fairly representative as regards length, age, and sex. A good part of this material, together with other odd samples, was used for a study on the time of formation of the winter band.

For data on the variability and distribution of scales in the different regions of the body, three specimens taken from the Hinds River (Ashburton) were specially suitable (see Page 500).

The data presented on the early development of the scale were obtained from an examination of fry reared at the North Canterbury Acclimatisation Society's hatchery at Christchurch. A number were set aside during November, 1930, and samples of twenty to thirty individuals were taken every fortnight up to the end of March, 1931. For larger specimens several samples were used that had been collected at odd times during 1928 and 1929.

SECTION III.—EARLY DEVELOPMENT OF THE SCALES.

The early development of the scale was studied in a series of hatchery-reared brown trout fry. The material consisted of 155 specimens of *Salmo trutta.* They ranged in length from 2.0 cm. to 8.0 cm. The eggs from which they were hatched were obtained during June, 1930, from fish stripped in the Lower Selwyn River. They hatched during the spring of 1930, and fortnightly samples were taken during December, 1930, January, February, and March, 1932.

The fry were preserved and treated for scale observations by the method given by Paget (1920). From specimens preserved in 5% formaldehyde, one-half (the right side) of the skin (epidermis and dermal layers) was removed in one piece and stained with haematoxylin. The results, as Paget also found, were very satisfactory, especially when the fish were placed in weak (30%) alcohol for a day or two previously to staining. In this way the epidermis was removed, thus giving a clear view of the dermal tissues in which the scales are developed.

My results, which agree substantially with those of Paget (1920), may be summarised as follows:—

The scale papillae were first observed along the lateral line, slightly posterior to the dorsal fin, when specimens were from 2.4 cm. to 2.8 cm. in length (see Fig. No. 1). From this area they gradually developed in an anterior and posterior direction along the lateral line, at the same time spreading dorsally and ventrally, until eventually the whole surface was covered. They tended to spread more quickly dorsally than ventrally. In several instances of fish ranging from 3.8 to 6.0 cm., fully formed scales with one to four circuli were found above the lateral line, and slightly posterior to the middle of the body, while those on the belly and immediately posterior to the gill covers were either just forming or entirely absent. Further particulars are given in the following table (No. 1):—

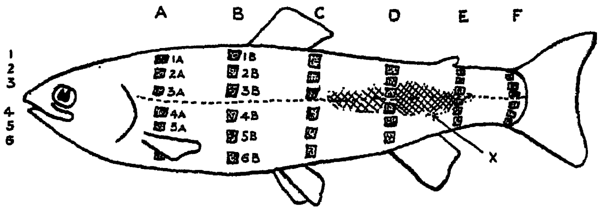

Fig. No. 1.—Diagram of trout, showing areas from which scales were taken. Area X indicates where scales first appear in young fish.

TABLE No. 1.

Av. length of fry (cm.) - - - -	2.6-3.0	3.1-3.5	3.6-4.0	4.1-4.5	4.6-5.0	5.1-5.5
Stage of scale development - -	papillae	platelets	platelets	fully formed	fully formed	fully formed
No. of circuli - -	—	—	—	1 to 3	2 to 5	3 to 7
Diameter of scale -	—	—	—	0.34 mm.	0.35 mm.	0.5 mm.
Anterior radius -	—	—	—	0.13 mm.	0.19 mm.	0.21 mm.
Posterior radius -	—	—	—	0.21 mm.	0.16 mm.	0.30 mm.

It should be remembered that fry living under natural conditions would be subjected to greater variations of temperature and food, which, according to Cutler, Gray, and others, have a direct influence upon scale-growth. In the case of wild fry a relatively wider range in the time of formation and subsequent growth of the scales would be expected. The present data indicate that the length of the fish when the scales first appear is on an average approximately 3.5 cm.

Section IV.—Variability of Scales from Different Regions of the Body.

Esdaile (1912) has shown in the case of the Atlantic salmon *(S. salar)* that scales from different parts of the body vary in length and number of circuli laid down. An intensive and systematic examination of the scales from various regions of the body is, as Esdaile points out, an essential preliminary to accurate work. She says: " How can comparisons be rightly made of scales from different fish when the extent of variation on one fish is not known? " Esdaile's work still remains the most complete study that has been carried out on this subject, and for this reason her results are given here in full. Her data were obtained from the examination of three individual salmon, viz.:—

(1) 10lb. fish taken from the Wye in August, 1910.
(2) 17lb. fish taken from the Wye in February, 1911.
(3) 26lb. fish taken from the Wye in March, 1910.

Esdaile came to the following conclusions:—

"(1) The number of annuli in each peronidium* increases from the head to the adipose fin, on both dorsal and ventral sides of the lateral line, and then decreases again towards the tail."

"(2) A great variation in the number of annuli (circuli) and in lengths of the scales taken from different parts of the same fish is clearly indicated. This was found on each of the three fish, but the results obtained seemed to be in no way correlated."

"(3) In a comparison of scales taken from positions at corresponding distances from the head on both the dorsal and ventral sides of the lateral line, it is seen that, as a general rule, the scales on the dorsal side have fewer annuli in each peronidium (annulus) than the scales from the ventral side."

"(4) I find it impossible to recognise any distinction between different types of annuli (circuli)."

It was thought advisable, for the present purpose, to carry out an intensive examination of the scales of three specimens of brown trout, each specimen, if possible, to be exactly the same length and weight. Three suitable fish were obtained in June, 1931, from the Hinds River, Ashburton County. Each of these fish measured exactly 12 in. in length and 15 oz. in weight. The length of the fish was taken from the tip of the snout to the end of the middle ray of the caudal fin.

Scales were taken from the right side of the body in transverse rows as shown in Fig. 1. The letters indicate the transverse rows from the anterior (A) to the posterior (F) ends of the fish. The numbers indicate the longitudinal rows from the dorsal (1) to the ventral (6) regions. Each of the areas from which scales were taken is therefore designated by its position on the transverse and longitudinal lines. Thus A 1 denotes that area (approximately ½ of an inch square) on the transverse row A and the longitudinal row 1. In each of the areas three scales are included, and the figures in the following tables are the average measurements or counts generally of three scales. It was found in some cases that all the three scales were imperfect, and in some cases a blank appears in the corresponding tables. It was found that when the three sets of tables corresponding to each of the three fish were combined, relatively few blanks remained.

Esdaile's tables show very significant variations in the length and number of circuli in the scales taken from practically identical positions (within the same square inch) in the different specimens. This variation is due, in the main, to the large difference in the size of the fish from which she obtained her material. Even by taking corresponding scales from fish of identical length and weight, individual variations will occur in the scales. Esdaile found that the number of circuli and the size of the scales were correlated either separately or together with the age of the fish from which they were taken.

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* Esdaile uses the terms *annulus* and *peronidium*. More recent usage replaces her *annulus* by *circulus* and her *peronidium* by *annulus*. This is indicated when quoting Esdaile by enclosing in parentheses the notation used in the present paper.

The notation used to designate the various scale measurements is shown diagramatically in Fig. 1. In the following account each of the characters examined will be considered separately.

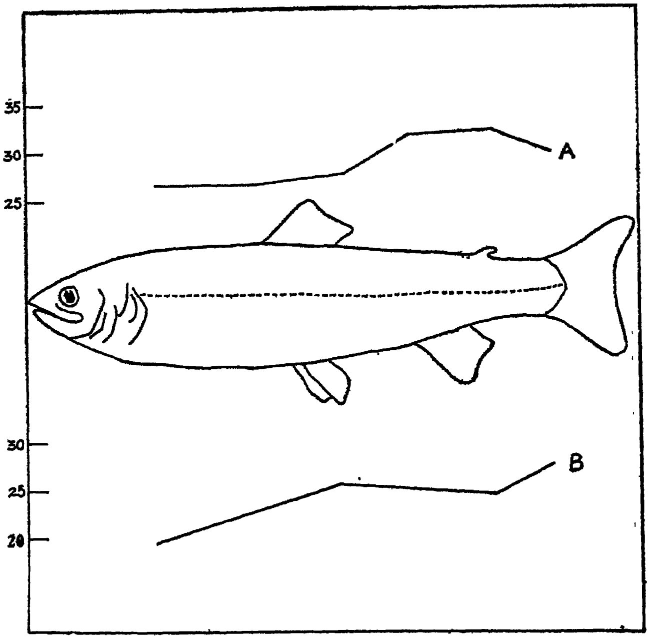

FIG. No. 2.—Graphs showing variation in length of anterior (A) and posterior (B) radii of the scales from different regions of the body.

Longitudinal Diameter of the Scales.

The longitudinal diameter corresponds to the anterior-posterior axis of the fish. In the tables that follow the scale measurements are given in actual micrometer divisions, eighteen of which equal one millimeter.

TABLE No. 2.

Average Length of Scales (18 micro-divisions = 1 mm).

		A	B	C	D	E	F	Aver.	
ANTERIOR	1	42.3	48.3	49.5	55.5	54.0	49.5	49.8	POSTERIOR
	2	49.0	48.5	50.0	56.5	54.5	53.2	51.9	
	3	54.0	57.0	60.0	59.2	59.0	56.5	57.6	
		Lateral Line.							
	4	46.0	48.5	60.2	52.7	61.0	51.0	53.3	
	5	40.0	42.5	47.0	49.5	54.5	61.5	49.2	
	6	31.0	42.0	53.0	66.0	59.0	55.5	51.1	
	Aver.	43.8	47.8	53.2	56.6	57.0	54.5		

It is seen from the above that the scales from different regions of the body vary considerably in total length. The anterior scales are generally shorter than those posteriorly situated. Anteriorly, the scales above the lateral line are larger than the corresponding ventral scales. The most satisfactory scales for age and growth determinations are those situated in the following areas:—C. 1, 2, and 3, D. 1, 2, and 3, and E. 1, 2, and 3. The following reasons are given for this statement:—

(1) The scales in this region (save those actually on the lateral line) are the first formed in the young fish.

(2) The circuli, and consequently the winter bands, are of a more definite character in the scales from this region than in the scales from other parts of the body.

It should be remembered that the above statement holds only for fish in general, for the character of the scales from this area exhibits only relative differences from the scales from other parts of the body. Further, scales from the same area of the body, in two individual fish of exactly the same size (length and weight), may differ more than scales taken from different parts of the body of the same fish.

Certain regions of the body are covered with scales which are without exception characteristic in shape and form of circuli. For instance, those situated at the base of the gill-covers, or at the base of the caudal fin, or again those on the belly may be cited. It has been found frequently that such scales may not show the first winter band. The lateral line scales are, of course, characteristic; they are with few exceptions useless for age determination. The abdominal scales, although varying considerably in form, are relatively broad compared with their length. In area they are the largest scales on the body, especially is this apparent in large fish.

Length of Posterior Radius.

The posterior portion of the scale is that which is exposed when the scale is in position in the scale pocket (see Plate 52).

TABLE No. 3.

Average Lengths of Posterior Radius of Scales from Various Regions of the Body.

		A	B	C	D	E	F	Aver.	
ANTERIOR	1	18.7	22.5	22.0	25.5	23.5	—	(22.4)	POSTERIOR
	2	22.0	20.2	24.0	25.0	24.5	—	(23.1)	
	3	23.5	27.5	28.0	24.5	25.0	—	(25.7)	
		Lateral Line.							
	4	20.1	21.0	29.5	26.0	26.5	24.0	24.5	
	5	16.0	18.5	23.0	23.5	22.0	30.0	22.2	
	6	14.0	23.7	26.0	25.6	—	28.5	(23.6)	
	Aver.	19.0	22.2	25.4	25.0	(24.3)	(27.5)		

From the above tables it is seen that the posterior radius varies more greatly than the longitudinal diameter of the scale. The posterior portion is generally largest in those scales situated above the lateral line.

Length of Anterior Radius.

The anterior portion of the scale is that which is enclosed in the scale pocket. From this part age and growth determinations are made.

TABLE No. 4.

Average Length of Anterior Radius of Scales from Various Regions of Body.

		A	B	C	D	E	F	Aver.	
ANTERIOR	1	26.6	25.6	27.7	31.0	29.5	—	(28.1)	POSTERIOR
	2	25.0	28.0	27.0	25.5	29.5	—	(27.0)	
	3	29.6	30.0	24.0	33.7	33.0	—	(30.1)	
				Lateral	Line.				
	4	26.8	28.0	32.0	31.0	35.0	28.0	30.1	
	5	28.5	24.7	26.7	27.0	33.0	32.0	28.7	
	6	17.2	23.5	27.0	39.0	—	29.0	(27.1)	
	Aver.	25.6	26.6	27.4	31.2	(32.0)	(29.7)		

The anterior portion of the scale does not vary to such an extent as other dimensions. Generally the anterior radius of the scale increases in length from the head towards the tail.

The Number of Circuli.

From the point of view of scale reading the character of and the constancy in the number of circuli in relation to the length of the anterior radius of the scale are of the greatest importance. There is little correlation between the number of circuli and the size of the scale in an individual fish. On the other hand, there is generally a close connection between the growth of the anterior radius and the production of circuli. This correlation will be shown later.

TABLE No. 5.

Average Number of Circuli.

		A	B	C	D	E	F	Aver.	
ANTERIOR	1	44.0	52.0	46.0	44.0	63.0	31.5	46.8	POSTERIOR
	2	50.0	56.0	48.0	60.0	45.0	50.0	51.5	
	3	54.0	56.7	47.0	47.0	51.0	49.0	50.8	
				Lateral	Line.				
	4	46.0	57.0	49.0	61.0	56.0	51.0	53.3	
	5	44.0	41.0	51.0	57.0	66.0	49.0	51.3	
	6	31.0	30.0	46.0	54.0	58.0	48.0	44.5	
	Aver.	44.8	48.8	47.8	53.8	56.5	46.4		

There is apparently an increase in the number of circuli per scale from the head to a point a little past the adipose fin, beyond which the number of circuli decreases.

Those scales above the lateral line and anterior to the dorsal fin possess a larger number of circuli than those below the lateral line.

The area of the body, where the scales possess the largest average number of circuli, is that from the posterior insertion of the dorsal fin to midway between the adipose and base of caudal fin, both above and below the lateral line. The scales from this area are generally large and most suitable for age determinations. There is apparently no significant difference in a dorso-ventral direction.

In one specimen of *Salmo salar* which Esdaile examined the number of annuli (circuli) varied from 76 to 121. She shows that this variation is not due to any one particular peronidium (annulus), but to variations in each of the peronidia (annuli). This variation she states is caused to some extent by definite local differences. "That is to say, speaking generally, the number of annuli (circuli) in each peronidium (annulus) increases from the head to the adipose fin, on both dorsal and ventral sides of the lateral line, and then decreases again towards the tail."

The present data from brown trout bear out fairly well the conclusions that Esdaile came to in the case of the salmon *(S. salar)*.

The results of the present investigation may be summarised as follows:—

(1) The scales from different regions of the body in the case of brown trout *(S. trutta)* vary greatly in length and in the number of circuli they contain.

(2) This variation is not entirely due to casual variations in the scales, but is caused by definite local differences.

(3) It would appear that these differences in the scales are to a more or less degree correlated with the time of scale formation in the young fish. As has been previously shown, the scales first appear along the lateral line, immediately below and slightly anterior to the adipose fin. The scales spread dorsally and ventrally from this area, but the rate at which they spread is slower below the lateral line than above. At the same time they spread anteriorly and posteriorly, ultimately covering the whole surface of the body. In the case of a fry 4.5 cm. long, fully developed scales with one to three circuli were found in the areas C 2, 3, 4, and 5; D 1, 2, 3, 4, and 5; and E 1, 2, 3, 4, and 5; while only minute scale platelets were forming on the remaining areas of the body.

(4) The number of circuli laid down in each scale increases from the head to the adipose fin and then decreases towards the tail. No significant increase or decrease was observed on the dorsal and ventral sides of the lateral line. This agrees with Esdaile's findings.

(5) A similar distributional variation is shown to occur in the length of the posterior and anterior radii of the scales.

(6) The average number of circuli laid down in each scale anterior to the dorsal fin is greater above than below the lateral line; posteriorly to and slightly beyond the adipose fin the reverse is indicated, namely, the ventral scales possess on an average a greater number of circuli. This was not observed by Esdaile in the case of the Atlantic salmon, for

she states: " In a comparison of scales taken from positions at corresponding distances from the head, on both the dorsal and ventral sides of the lateral line, it is seen that as a general rule the scales on the dorsal side have fewer annuli in each peronidium (annuli) than the scales from the ventral side."

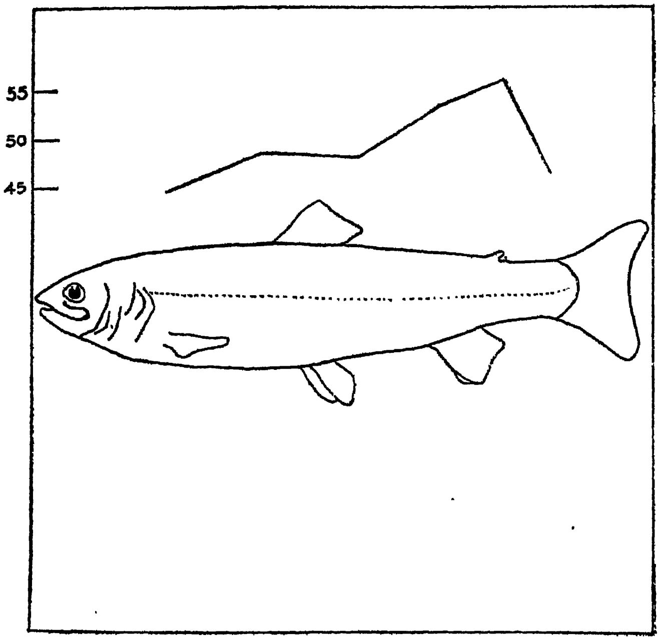

Fig. No. 3.—Graph showing variations in number of circuli on the anterior radii of the scales from different regions of the body.

SECTION V.—FORMATION OF WINTER AND SUMMER ZONES IN THE SCALES.

Information on the points to which we now turn is of the greatest value, and should, as Thompson (1904) says, be properly worked out for each species of fish from which it is desired to obtain data by scale examination.

It is quite evident that the nature of the winter bands, and the time of the year during which they are formed, varies in individual fish from the same locality, and to a much greater extent in individuals from different localities. The present material does not permit of an investigation being made into the variability of the time of formation of the winter band in fish from different localities.

An interesting phenomenon is indicated by the present study, namely, that the North Island fish show relatively wide winter bands on their scales, while those of the South Island, and especially in Southland, show relatively narrow bands.

The data obtained by measuring the increasing distance and number of circuli of the peripheral band on the scale of fish taken each month during the course of a year are given in the following tables (Nos. 6 and 7, and Fig. 4).

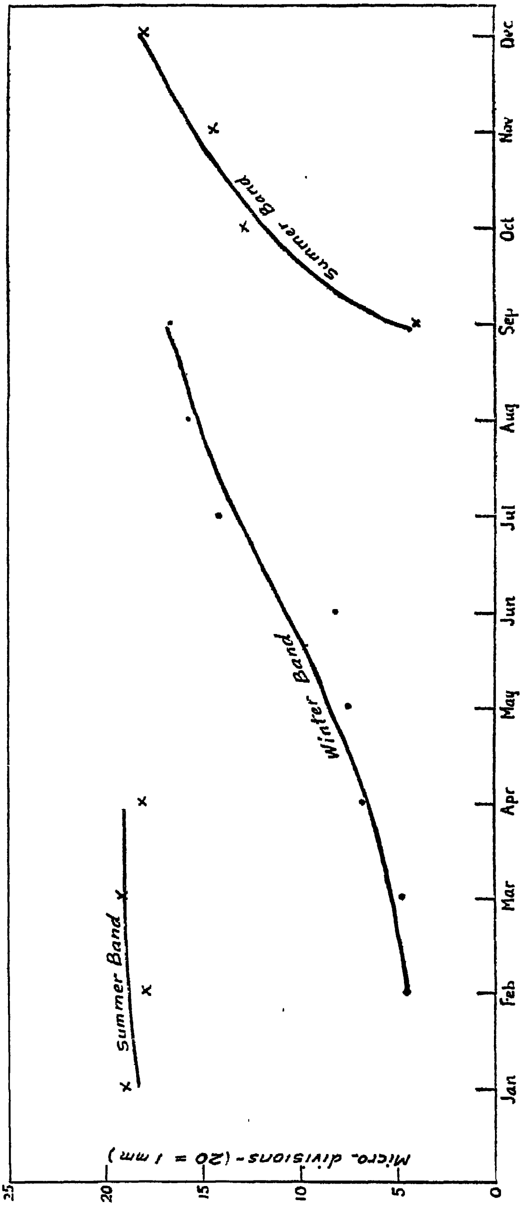

FIG. No. 4.—Showing formation of summer and winter bands.

Fish with two completed bands of narrow circuli on their scales were taken, and the data given relate to the formation of the third band.

TABLE No. 6.

Time of year during which the Bands of Broad and Narrow Circuli are laid down in the Scale.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
				Broad Circuli (Summer Band).								
Peripheral band—												
No. of circuli in peripheral Band	19.00	18.00	19.25	18.20	—	—	—	—	4.00	12.95	14.50	18.14
Width of peripheral band ..	6.91	9.50	14.25	9.00	—	—	—	—	3.00	7.16	7.77	11.90
				Narrow Circuli (Winter Band).								
No. of circuli	—	4.50	4.75	6.75	7.50	8.21	14.13	15.75	16.66	—	—	—
Length (in micrometer divisions)	—	2.67	2.34	2.87	6.11	4.11	7.50	8.30	8.83	—	—	—

TABLE No. 7.

Number of Fish per cent. of each Monthly Sample Showing Broad or Narrow Peripheral Band.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Broad ..	100.0	67.0	22.0	20.0	—	—	—	—	40.0	100.0	100.0	100.0
Narrow ..	—	33.0	78.0	80.0	100.0	100.0	100.0	100.0	60.0	—	—	—

The information obtained from the above tables may be summarised as follows:—

(1) The band of narrow circuli is laid down in the scale generally during the autumn and winter months of the year.

(2) The bands of broad circuli are formed during the spring and summer months.

(3) The bands of narrow circuli may begin to form as early as February, or, on the other hand, summer growth (broad circuli) may persist until April. The majority, however, show the beginning of a winter band on their scales by March.

(4) Early in September the summer band begins to develop, and by the end of October the majority show summer growth to be taking place.

In some cases the winter check is formed by only two, three, or four circuli. In such cases there are grounds for believing either:—

(1) That growth, at any rate of the scale, has for a period, probably June and July, completely ceased, resuming to produce summer circuli towards the end of August or early in September. This would be expected where winter conditions are exceptionally severe. Or

(2) That summer growth has persisted well into the autumn, and very early growth occurred in the following spring.

It is probable that the first condition may occur in the southern portion of New Zealand, while the second condition may be the rule in the more equable conditions prevailing in the northern districts. However, the data upon this point are of too meagre a nature to justify definite conclusions. The significance of this nevertheless should not be lost sight of in future investigations.

Fig. No. 4, plotted from Table No. 6, shows the rate of production of circuli during the year.

We may conclude that the terms summer and winter bands can be applied to the bands of broad and narrow circuli respectively as observed on the scales of brown trout in New Zealand. As a corollary to this we may state that only one band of narrow circuli and one band of relatively wide circuli are laid down during the year. Thus by the enumeration of these alternate bands of wide and narrow circuli the age of the fish in years may be ascertained.

It is interesting to correlate the time of formation of the summer and winter zones in the scales with the mean monthly temperature of the water in which the fish have lived.

At the present time the necessary data on water temperature are not available for a complete treatment of this subject.

Such a study should be undertaken in a particular locality from which scale and temperature data could be collected side by side over a period of several years.

In Table No. 6 are given the mean monthly temperatures for four localities, corresponding roughly in latitude with the localities from which the present scale material was obtained. These temperatures are shown graphically in Graph No. 2.

TABLE No. 8.

Mean, Maximum, and Minimum Monthly Temperature from the Various Localities.

Locality.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual Range.
Feilding (N.I.)—													
Min. ..	15.0	16.0	—	11.0	9.0	6.5	5.4	5.0	15.0	—	13.0	15.0	4.8° C.
Max. ..	20.0	22.0	—	16.0	14.0	10.0	9.0	8.0	16.5	—	18.0	24.0	
Mean ..	17.7	18.7	—	13.9	11.2	8.0	7.2	6.7	16.0	—	16.1	18.3	
Canterbury—													
Avon R. (S.I.):													
Min. ..	13.0	12.0	13.0	11.0	10.5	8.0	8.5	9.0	8.5	11.0	12.0	13.0	2.9° C.
Max. ..	16.5	15.5	14.5	14.0	12.5	11.5	10.5	11.0	13.0	14.0	15.0	16.5	
Mean ..	14.5	14.2	13.8	13.0	11.5	9.9	9.7	10.2	11.2	12.3	13.6	14.5	
anterbury—													
Selwyn R. (S.I.):													
Min. ..	—	—	—	—	9.5	6.0	4.5	—	—	—	—	—	
Max. ..	—	—	—	—	11.0	9.0	7.5	—	—	—	—	—	
Mean ..	—	—	—	—	9.8	7.6	6.7	—	—	—	—	—	
tago—													
Orona R. (S.I.):													
Min. ..	8.5	9.0	7.0	—	—	1.0	1.0	1.0	1.5	4.5	5.5	8.0	5.3° C.
Max. ..	15.5	12.5	12.0	—	—	7.5	3.5	4.5	7.5	9.0	10.0	17.5	
Mean ..	11.1	10.6	9.9	—	—	3.2	1.5	3.0	4.7	6.7	8.2	10.7	

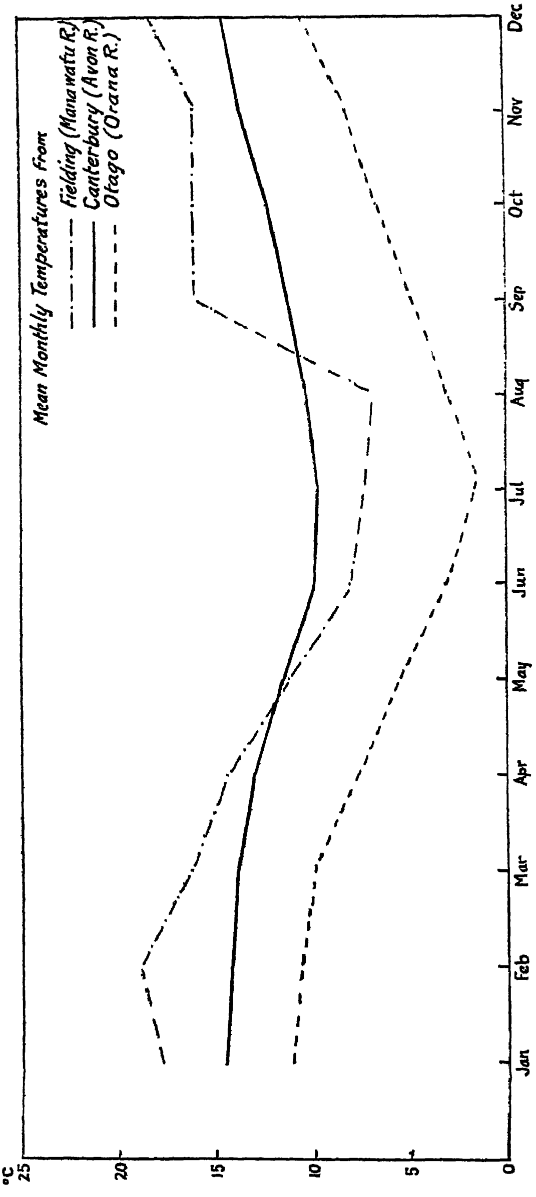

Fig. No. 6.

Bearing in mind the meagre nature of the data upon which the above table is based, attention may be drawn to the following apparently significant points:—

(1) During the spring, summer, and autumn months the temperature at Feilding in the North Island is significantly higher than in Canterbury or Otago.

(2) The Otago temperatures are considerably lower throughout the year than the Feilding and Canterbury records.

(3) The increase in temperature during the spring is more rapid in Feilding than in Otago and Canterbury.

Bhatia (1932) has investigated the effects of temperature on the width of circuli in the scales of rainbow trout *(Salmo irideus)*. He found that, irrespective of high or low temperatures, abundant nutrition produced broad circuli, and deficient nutrition produced invariably narrow circuli. He states: " The temperature seems to have no effect, except that at low temperatures the fish are less inclined to feed than at higher temperatures, owing, probably, to the lower rate of metabolism. In Nature this fact, coupled with the scarcity of food in winter, must, therefore, be regarded as the causative factor for the production of narrow ' winter ' rings."

Percival (1932) has shown, however, that there is abundant food available for trout in New Zealand throughout the year.

In four collections made during July, 1930, in the lower Selwyn River, he found on an average 607 organisms per sq. foot.

It would also appear from the work of Percival and Whitehead (1930), on the River Wharfe (England), that there does not occur in English streams a very significant decrease in abundance of aquatic organisms during the winter months.

With regard to the opinion that trout feed little, or not at all, at low temperatures, Percival (1932, pp. 18) makes the following interesting statement: " That this is not so throughout the Dominion is evidenced by the fact that freshly spawned female fish taken in early August, from Lakes Taylor and Sheppard, were gorged with *Corneocyclas* (a small bivalve mollusc), *Potamopyrgus*, various caddis larvae, chiefly *Pycnocentria, Gobiomorphus*, and vegetable fragments. A male and female, newly spawned, were gorged with freshly deposited trout-eggs. The water temperature was 7½° C. (45° F.). The indications were that, in the lakes under consideration, fish commenced to feed voraciously as soon as they had recovered from the act of spawning."

SECTION VI.—GROWTH OF THE SCALE IN RELATION TO THE GROWTH OF THE FISH.

Upon the validity of the proposition, that an annual increment in the length (or some other dimension) of the scale maintains a constant ratio with the corresponding annual increment in body length throughout the life of the fish, depends the accuracy of the scale method. It is essential that data should be available to indicate what correlation exists between the growth of the scale and that of the fish in length.

Van Oosten (1929) gives an excellent historical account of this subject.

For the purpose of the present investigation, 510 brown-trout scales were measured. The majority of these fish were obtained from the Tamiki River, near Dannevirke, during the winter of 1931.

From each fish a sample of scales was taken from the area (X) shown in Figure No. 1. Earlier in this paper the extent of variation exhibited in the scales from different regions of the body was shown. Considering the variation which occurs in the size of and in the number of circuli in the scales from this area of the body, it was considered that the average of five normal scales from this area would give sufficiently accurate results for the present purpose.

In the determinations of age and growth of the trout, we are concerned only with that part of the scale which is enclosed in the scale pocket—namely, the anterior radius. In the present paper only this measurement is dealt with.

The results are given in Fig. No. 6 and Table No. 9.

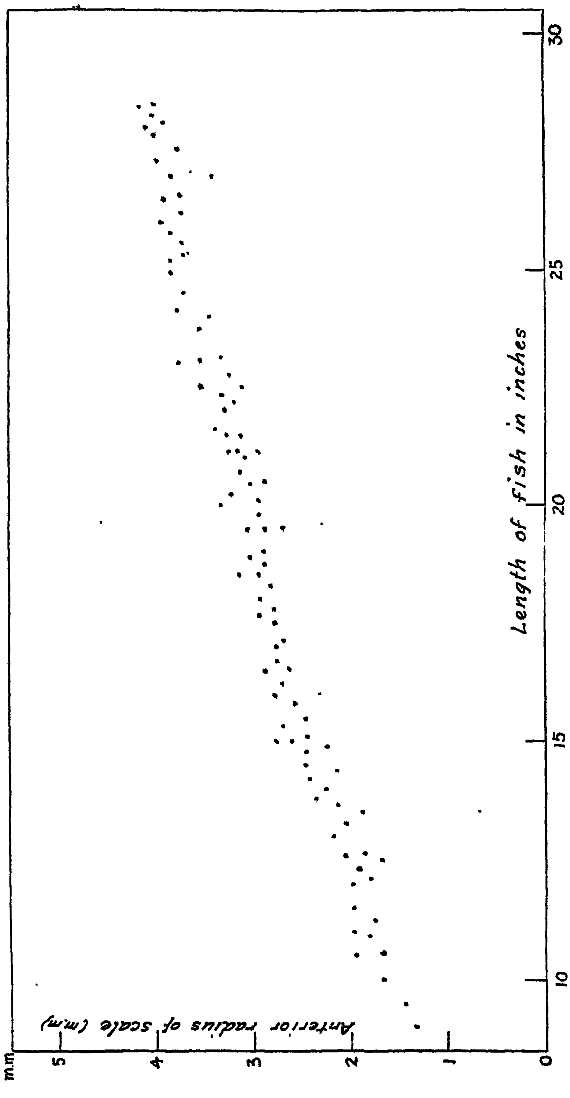

FIG. No. 6.—To show the length of the anterior radius of the scale in relation to the length of the fish.

TABLE No. 9.

Showing Mean Rate of Production of Circuli in the Scales of Brown Trout.

Length of Fish in Inches.	Average number of Circuli in Scale.	Length of Fish in Inches.	Average number of Circuli in Scale.
9.0– 9.9	52	19.0–19.9	86
10.0–10.9	51	20.0–20.9	94
11.0–11.9	59	21.0–21.9	94
12.0–12.9	56	22.0–22.9	92
13.0–13.9	63	23.0–23.9	100
14.0–14.9	68	24.0–24.9	99
15.0–15.9	73	25.0–25.9	101
16.0–16.9	73	26.0–26.9	104
17.0–17.9	77	27.0–27.9	123
18.0–18.9	81	28.0–28.9	111

Finally, there remains to examine the third, and last, assumption upon which the validity of the scale theory is based—namely, "that the scales remain constant in number and retain their identity throughout the life of the fish." It is well known that the number of scales situated along the lateral line in any one species of fish is practically constant for the individuals of that species. That is, the number of scales does not increase as the fish increases in length.

We have also another line of evidence, in what is known as imperfect centred scales. Normally, a scale has a very small centre; if, however, a scale at some time or other is accidentally rubbed off, another scale will grow to take its place. In these new scales the centres are large; actually the size of the centre is proportional to the size of the scale which was displaced.

Such imperfect scales are frequently found, and are obviously of no use for age and growth determination.

SECTION VII.—SUMMARY.

(1) Scale papillae are first observed along the lateral line, slightly posterior to the dorsal fin. From this area they gradually develop in an anterior and posterior direction along the lateral line, at the same time spreading dorsally and ventrally, until eventually the whole surface of the body is covered. They tend to spread more rapidly dorsally than ventrally.

(2) The average length of the young fish when scales first make their appearance is approximately 3.5 cm.

(3) The scales from different regions of the body in the case of the brown trout *(Salmo trutta)* vary considerably in anterior-posterior diameter, and the number of circuli occurring along the anterior radius. This variation is not entirely due to casual variations in the scale, but is caused by definite local differences, which may to a certain degree be correlated with the time of scale formation in the young fish.

(4) The number of circuli laid down in any one scale increases from the head to the adipose fin, and then decreases to the tail.

(5) A similar distributional variation is shown to occur in the length of the posterior and anterior radius of the scales.

(6) The average number of circuli laid down in each scale, anterior to the dorsal fin, is greater above than below the lateral line, but posteriorly, and slightly beyond the adipose fin, the reverse is indicated—namely, the ventral scales possess on an average a greater number of circuli.

(7) The nature of the winter bands, and the time of year during which they are formed, varies in different individual fish taken from the same locality.

(8) The bands of narrow circuli may begin to form as early as February, or, on the other hand, summer growth (broad circuli) may persist until April. The majority, however, show the beginnings of a winter band on their scales by March.

(9) The bands of narrow circuli, seen on the scales of brown trout in New Zealand, are laid down generally during the autumn and winter months of the year, while bands of relatively broad circuli are formed during the spring and summer months.

(10) Early in September the summer band begins to develop, and by the end of October the majority show summer growth to be taking place.

(11) There is a definite correlation between the growth of the fish and the growth of the scales.

ACKNOWLEDGMENTS.

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The writer wishes to express his thanks to the members of the Committee, especially is he indebted to Professor E. Percival, of Canterbury College, and Mr M. H. Godby, of Christchurch, for valuable assistance and advice in connection with the preparation of this paper, and to Mr D. F. Hobbs, Christchurch, for specimens of trout fry.

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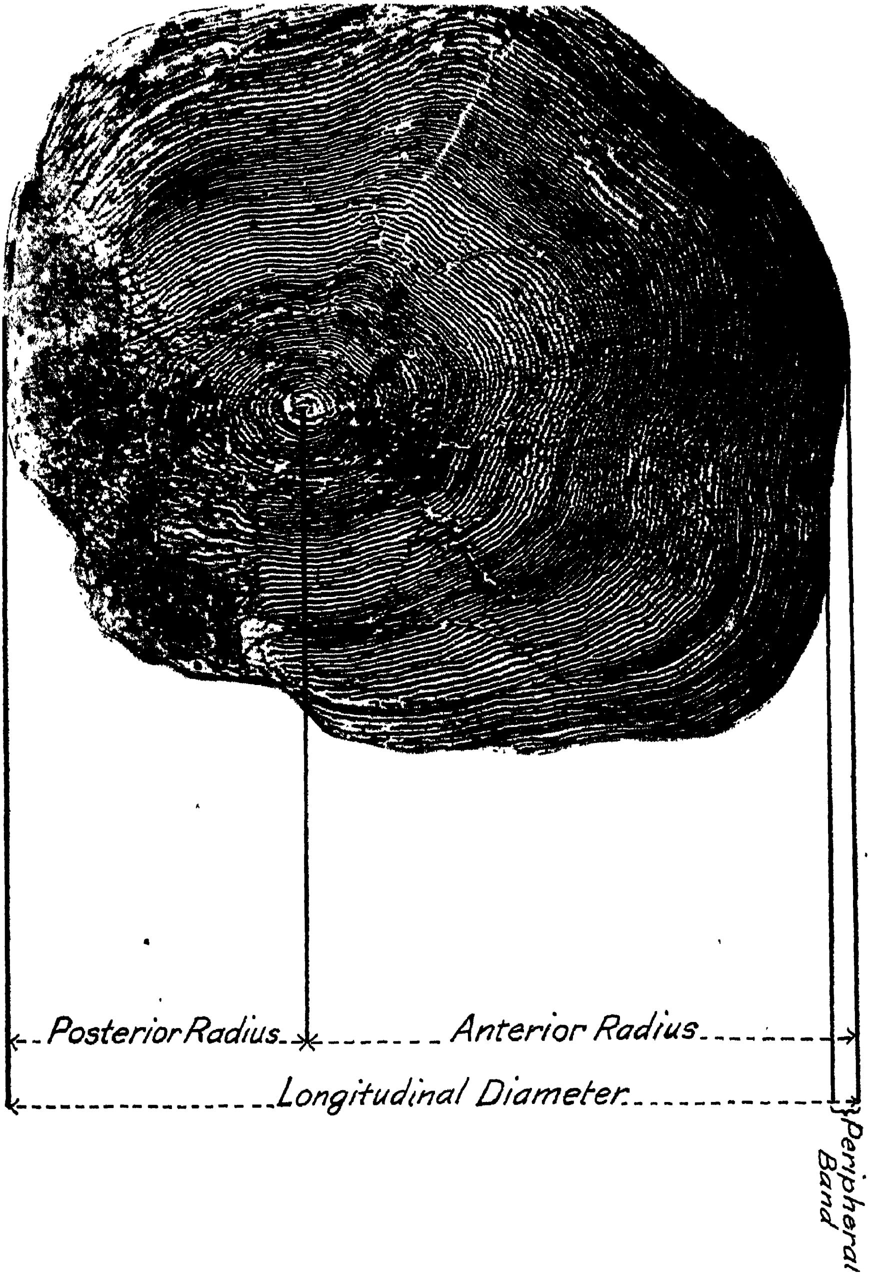

Scale of brown trout.

A Microscopical Study of the Structure of the Leaves of the Genus Pinus.

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THE introduction and propagation of many species of exotic conifers have been proceeding in New Zealand for approximately eighty years, and there now exist throughout the Dominion specimen trees of different ages as well as many specimens which exhibit individually characteristic growth or display forms varying from the type, thus rendering unreliable their identification from macroscopical characters.

At the instigation of Mr A. Hansson, Chief Inspector of Forestry, this study was carried out during 1929 to ascertain the possibilities of analysing the microscopic characters of leaves of various species of the genus *Pinus* in such a way as to form a key which could be used to verify the identification of the species by macroscopic characters. In many cases the latter differ within a species with variation of site and growing conditions, age, etc., hence identification by such factors may not be conclusive. It is at this stage that the examination of the microscopic characters of the leaves may furnish discriminatory evidence enabling a conclusion to be arrived at.

With this object in view, as many species as were available from different localities in New Zealand were examined, and their characters were then analysed to produce the appended key embodying diagnostic characters of forty species. Any conclusions arrived at to date must be considered as preliminary only, as variation of habitat, origin of the type, etc., may be found, on subsequent examination of a greater diversity of specimens, to affect the structure, and hence the diagnostic characters assigned in this table. The species included in the study are designated according to the names by which the original specimens were known in the Forest Service nurseries.

Technical Procedure.

The cross section from the middle of an average needle was used as the basis of examination, and wherever any indication arose of variation in structure, sections were cut at different positions along the length of the needle in order to counterbalance differences found to be due to rearrangement of tissues near the tips or bases of the leaf.

Sectioning was at first carried out freehand, using a razor with a blade flat on one side and cutting into material mounted as a bundle of several leaves tied tightly together.

Satisfactory sectioning was carried on by this means, but an attempt was then made to reduce the time spent on tool sharpening by adopting the use of safety razor blades mounted in a patent holder. This form of microtome knife was constructed by the Chief Inspector, and was used at first for hand cutting, in conjunction with a hand microtome, but by a little adjustment it was made to fit into a Bausch and Lomb swinging microtome, and was used thus for most of the sectioning work.

The material was mounted for cutting in a paraffin wax block by placing three or four short lengths of the needle upright in some warm wax poured into the cavity of a brass hand microtome, and then filling to the top with melted wax (the wax was found to cut most smoothly and easily when it had been kept below a temperature of 80° F. while melting, and was used soon after being cooled). The block could then be screwed up out of the holder and trimmed to fit into the microtome. Great difficulty was experienced in preventing the wax shavings from curling up as the cut was made, but it was found absolutely necessary to prevent this, as the sections mounted in curled wax almost invariably emerged with broken tissues. The most satisfactory method found was to keep the melting temperature of the wax low, and to have the material as soft and wet as possible.

Material.

Wherever available, freshly collected material was preferred for sectioning, but where this was not available it was found to be most satisfactory to cut needles into short lengths and leave them immersed in fresh water in a stoppered test tube until required for cutting. In the case of hard needles, glycerine added to the water (about 1 in 20) helped to soften them for cutting.

It is much more difficult to cut thin and perfect sections from needles of certain species than from others. This is due to the presence or to the arrangement of the schlerozed cells just below the epidermis, which in some instances serve to turn the fine blade-edge of the cutter, while in other cases the thin-walled cells between groups of hypodermal sclerenchyma are not strong enough to hold the tissues together when cut into very thin sections, and difficulty is experienced in obtaining a perfectly whole section by the end of the mounting process.

Preparation of Slides.

It was found necessary to stain sections in order to show up the structure for photography. For this purpose, fuchsin or saffranin were found to be most satisfactory as a cell-wall stain, the former acting on lignified tissue, and to a certain extent also on cellulose walls, while saffranin stained both lignified and cellulose walls together with certain cell contents. To differentiate the cells of the mesophyll from those of resin ducts in the cases where the latter were not sclerozed (lignified), eosin was found to be a good agent, although this stain was not satisfactory as a tissue stain.

The following procedure was adopted for preparation of the sections, and was varied, according to the type of material, in such details as the times necessary for each treatment or by the exclusion of certain steps in the process.

Fresh material was cut from water and was kept wet by continual moistening whilst being cut. Sections were then placed in 50% (approximately) alcohol for a minute and transferred into either absolute alcohol or methylated spirits and left until all the green colouring matter was extracted—a matter of a half to several hours according to the material. The sections were then transferred into a 1½ inch watch glass containing a drop of staining solution in the glass full of water. If sections were of a fragile nature they were taken back through 50% alcohol into the stain. The time of staining varied from fifteen minutes to one hour, and sections were then passed through 50% alcohol again into absolute alcohol to rinse out excess of stain. If necessary, a second absolute alcohol rinsing was given. The stained material was then placed into clove oil for about 15 to 30 minutes to clear, and into xylol to dissolve the oil and also any paraffin-wax which adhered to the section from the cutting process. From xylol the sections were mounted into Canada balsam.

When using other stains the following procedure was adopted:—

Eosin: A 0.5% solution, made by dissolving 0.1 gm. dry eosin in 20 c.c. of 50% alcohol was used as stain. The sections were cleared from chlorophyll in absolute alcohol. Placed in eosin solution as above, diluted with water about 10 times, and left for from half an hour to several hours. Removed into acetic acid (2%) solution for a few minutes. Dehydrated in absolute alcohol. Cleared in clove oil or xylol, or both. Mounted in Canada balsam.

Saffranin: Used a solution of 1 gm. of alcoholic saffranin in 50 c.c. absolute alcohol and 50 c.c. water. After clearing, the sections were left in the diluted stain (2 or 3 drops per watch glass of water) for about 15 minutes, then transferred through 50% to 70% alcohol (if necessary, to absolute alcohol) and completed as above.

Gentian-Violet: A standard solution of unknown strength was used. Sections, after clearing in methylated spirit or absolute alcohol, were transferred to water and thence placed in the stain for 15 to 30 minutes, washed in distilled water, and then rapidly through absolute alcohol into clove oil. The latter dissolves out the stain rapidly, so that when just at the right strength of staining, the sections were removed into xylol and thence mounted.

Photomicroscopic Procedure.

Photomicrographs were made of normal sections of each species. The apparatus used was assembled and set up by the Chief Inspector and Forest Guard Johnson. A Graphic camera with the lens removed was superimposed over a microscope, the eye piece of which was removed, the end of the tube being connected with the lens aperture of the camera by an overlapping, double roll of black velvet. The camera and microscope were clamped on to a wooden frame, while illumination was obtained by fixing a bulb socket on to the edge of the wood frame and using a 75 watt frosted bulb, daylight being excluded by covering the microscope, etc., with a green cloth during the exposure (see Fig. 2). A Wratten K2 filter was fixed just inside the camera lens aperture.

In order to focus more easily than on the ground glass plate, a blank plate was developed, fixed, and utilised as a focussing screen, using a magnifying glass for fine focussing; for roughly focussing the image, a ground glass plate was slipped into the camera at the back of the screen. After experimenting with plates of several types and speeds, it was decided to use Panchromatic B. Imperial plates with an average exposure of one minute. This procedure was followed by Forest Guard Forbes, who carried out most of the photographic work.

No appreciable difference was experienced in the suitability for photography of the different microscopic stains used in the preparation of the sections.

General Discussion of the Characters of Leaves.

Several attempts have been made by different workers to find some one variant factor by which pines can be clasified, but so far it has not been possible to confine identification to one character only, and it has been found necessary in all classifications to employ several factors as determinants; this was found to apply in the present study also.

The structure of a typical pine leaf is shown in Figure 3, but each species has its own characteristic structure varying more or less from the type. Species may vary in " fundamental characters," i.e., shape of leaf, number and arrangement of ducts and stomata, or character of hypodermal layers, or the fundamental structure in one species may compare exactly with that of a leaf of another species displaying similar characters but differing widely in appearance, owing to minor characteristics. The typical pine leaf is made up of the outer covering skin, the ground or assimilating tissue, and the conducting tissue, but certain botanical features are of particular diagnostic value in this genus, and these are noted below.

In most pine species the needle possesses an inner covering layer of hypodermis, which may consist of one or more rows, immediately inside the epidermis, of specially thick-walled cells whose chief object is the mechanical strengthening of the leaf structure and possibly, in part, the insulation of the inner tissues from exterior influences. In certain species an extra row of thin-walled regular cells, with no cell contents, is interposed between the epidermis and the first thickened hypodermal layer. This is the " water layer," and so far no specific reason for its existence can be given. Its presence or absence, however, is constant within a species.

Resin canals in the pine needle are formed by the modification of certain cells of the mesophyll parenchyma to act as secretory canals. In section these ducts appear as a ring of a few or many ovate cells with thickened walls surrounding a central passage lined with thin-walled secreting epithelial cells which are continually disintegrating and throwing their contents of resin into the duct. When situated immediately adjoining the epidermal or hypodermal layer of cells, the resin ducts are termed " marginal " or " peripheral "; if placed at the inner edge of the mesophyll and adjoining the endodermal layer they are " internal "; when the resin ducts appear surrounded by mesophyll cells they are " median."

In conjunction with the fibro-vascular bundles of the centrally situated fibro-vascular strand of the leaf occur specially adapted conductive tissues—the transfusion tissue and the albuminous cells—while in some species there are found one or more plates of parenchyma cells between the rows of xylem cells. These appear in cross-section of the bundle as a single row of elongated cells, traversing the xylem and phloem radially, and are described as " parenchyma rays."

The numbers, arrangement, or composition of the structural leaf elements may differ in various species, and thus give a means for the identification of different species. Englemann* attempted to classify pines by the position of the resin ducts, but it would appear that though in general this is constant between species, the leaves within a species vary, and additional resin ducts are often found present and placed in other than the typical position. For example, in *P. halepensis* (Fig. 9) the resin ducts are typically placed against the hypodermis, but in some needles an extra, medianly placed duct was found. In *P. laricio* (Fig. 10) the majority of ducts are median, but two or three are present as internal ducts adjoining the endodermis.

The position of the stomata acts as a diagnostic character when taken in conjunction with other features, but again the number of stomata cannot be relied on as constant, since the presence or absence of these organs depends very largely on physiological conditions, e.g., in xerophytic species or in individuals grown under xerophytic conditions the number of stomata per area of leaf surface is reduced compared with the number borne by the same species when grown in a warm, humid situation.

In the present investigation it has been found that, although the numbers of stomatic lines may vary from leaf to leaf within a species, their position, whether borne on all or only on certain faces of the needle, remains constant.

Where stomata are not present on all faces, they are absent on the outer face or morphological lower surface of the leaf as in *P. Armandi, P. strobus, P. excelsa, P. monticola.*

Discussion of the Classification used in the Key.

From the material examined to date a tentative key was drawn up for the identification of pines from the microscopical characters of their leaf section. This was based on the following diagnostic characters, which are applied in the order given and considered to be " fundamental characters " sufficiently constant within a species to be used for the discrimination of species.

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* Englemann, "Genus Pinus" and "Revision of the Genus Pinus."

(a) Shape of cross section of needle.
(b) Number and position of resin ducts.
(c) Number and position of stomata.
(d) Nature of hypodermal tissue.

(a) The shape of the needle section follows on the number of leaves in the fascicle. Roughly, 5-needle pines have a triangular leaf section, the section of 3-needle pines is a sector of a circle, and leaves of 2-needle fascicles are semi-circular in section.

In the case of certain pines which bear both 2 and 3-needle dwarf shoots, two distinct forms of leaf are found within the species, e.g., in *P. caribaea,* which produces leaves of semi-circular outline and also those which cut to a sector. In the case of *P. caribaea,* at least, the fundamental structure does not differ with the different shape of leaf (Figs. 21, 22).

In *P. Lambertiana, P. excelsa, P. Torreyana* it sometimes occurs that the leaf shows a distinctly 4-sided outline, the additional angle being marked by an enlarged corner epidermal cell, but the extra surface is very narrow, and in no case was found to bear stomata, although these may have been borne on all the other leaf faces.

(b) As noted above, the number of resin ducts varies, within certain limits, with individual leaves, and though it functions as a broad, indicatory factor in distinguishing between species whose general structure is otherwise similar, it is too variable to act as an indentification character alone; e.g., *P. massoniana* with 6 to 8 ducts, *P. lambertiana, P. strobus* ranging from 2 to 3 ducts, *P. coulteri* with leaves showing 2, 4, or 6 ducts, *P. laricio* 8 to 10, and *P. densiflora* specimens with 7 to 10 ducts.

The position of the resin-ducts is found to be constant, but here again minor variations occur in individual trees or leaves within one species. In *P. halepensis, P. Armandi, P. yunnanensis, P. patula, P. caribaea, P. laricio, P. tuberculata,* and *P. resinosa* resin ducts occur in more than one position, the normal distribution being evidently augmented by scattered ducts of another origin. This occurs in *P. patula* (Fig. 26), where the normal ducts are median, but are increased in some instances by additional smaller peripheral ducts. In *P. yunnanensis* occur two median ducts placed in the normal position at either lateral angle, and the six peripheral ducts scattered on both faces appear to be formed as a breaking apart of a group of hypoderm cells, and are probably rudimentary.

(c) The number and position of the stomata, as discussed above, are not sufficiently discriminating to act alone as a basis of classification, but though the number varies considerably—even in different leaves of the same species—their position is a constant factor, and serves to distinguish species. In the case of *P. flexilis* (Fig. 39) and *P. strobus* (Fig. 43) the species are not distinguishable as regards leaf section, number and position of resin-ducts, or number of hypoderm layers, but they differ in that *P. flexilis* has stomata on all three faces, while *P. strobus* possesses approximately the same number of stomatic lines per surface, but these appear only on two surfaces. The cross sections of *P. strobus* and *P. excelsa* (Figs. 43, 38) are identical as to fundamental characters, and the only distinguishing features are shown in the number of stomata, which in this case appears to be fairly constant, in *P. strobus* the stomata being always in groups of two or three, while in *P. excelsa* the stomatic lines run in fives.

(d) The nature and number of the hypodermal layers are the most variable of the characters used in the key classification. The value of this layer as a distinguishing feature appears in certain cases, notably in the instance of the *P. ponderosa* group, where the characters of the leaf section of the types recognised as growing in New Zealand, viz., *P. ponderosa*, *P. Jeffreyii*, and *P. scopulorum*, are identical, even the stomatic lines showing no clear distinguishing features, except in the hypodermal layer.

Examination of the leaves of these three types as grown in Rotorua showed, however, that *P. scopulorum* differed from both *ponderosa* and *Jeffreyii* types in having a distinct " water layer " of hypoderm cells. *P. Jeffreyii* is distinguished further by having not more than two hypoderm layers, one of which is a pseudo water layer, in contrast to *P. ponderosa*, which possesses three to five rows of sclerenchymatous cells, and to *P. scopulorum*, which shows two sclerenchymatous layers in addition to the water layer.

Mirov, writing on the distinguishing characters of the various *P. ponderosa* types growing in North America, shows in *P. ponderosa*, or " typical western yellow pine," a consistent presence of the water layer, while in typical *P. Jeffreyii* the sclerenchyma immediately adjoins the epidermal cells.* In comparing this finding with the characters of the types listed in New Zealand some discrepancy is noticed, and it would appear that, basing comparison on this morphological difference, the type which is known as the " *scopulorum* " type in New Zealand corresponds with the " typical western yellow pine " of North America, a fact not borne out in macroscopical and growth characteristics.

As a further example of the use of this character it may be noted that *P. luchuensis* (Fig. 11) and *P. thunbergii* (Fig. 19) or *P. Banksiana* (Fig. 6) agree in all the essential characters, but the first species is distinct from both the others in having no water layer.

From the present study a " water layer " is shown to be present in the following species:—

Among 3-needle pines in *P. scopulorum, yunnanensis, caribaea, rigida, tuberculata, radiata, leiophylla, patula, taeda;* in 5-needle pines in *P. Armandi, Lambertiana, strobus, excelsa, Montezumae;* in the 2-needle group in *Massoniana, pinaster, sylvestris, Banksiana, Thunbergii, muricata, Murrayana, densiflora, resinosa, caribaea.*

Work on the examination of the anatomy of pine leaves has been carried out, among others, by Englemann, Matthews, Coulter and Rose, and to a lesser extent by Dallimore and Jackson. On comparing the results of the present study with information published by these workers, certain differences were found to occur in various species. This may be due to consistent difference in structure of New Zealand-grown specimens, or may be due to individual variations which have not been corrected by taking a sufficient number of sections, either on the part of past workers or myself.

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* *Journal of Forestry.* Vol. XXVII, No. 2 (1929).

A list of the differences which have been noted are given below:

Species.	Characters Found in this Study.	Characters According to Other Authors.
P. Armandi	Resin ducts: 2 marginal, 1 median	Resin ducts: 2 median (Dallimore & Jackson).
P. Banksiana	Resin ducts: 2 median	Resin ducts: marginal (Dallimore & Jackson).
P. canariensis	„ „ 2 marginal	Resin ducts: median (Dallimore & Jackson).
P. cembroides var. *monophylla*	„ „ 2 marginal	Resin ducts: 5 median (Dallimore & Jackson).
P. halepensis	„ „ 5 marginal 1 median	Resin ducts: marginal (Dallimore & Jackson).
P. Lambertiana	„ „ 3 marginal	In primordial leaves resin ducts are peripheral, while in permanent leaves they are median (Matthews).
P. monticola	Leaf section: 4 sided	Triangular (Matthews).
P. Murrayana	Resin ducts: None	Resin ducts: median (Dallimore & Jackson).
P. palustris	„ „ 2 internal	Resin ducts: median (Dallimore & Jackson, Elwes & Henry).
P. patula	„ „ 2 median 2 internal	Resin ducts: median (Dallimore & Jackson, Elwes & Henry).
P. pinaster	„ „ 9 median	Resin ducts: 2 median (Matthews).
P. pinea	„ „ None	Resin ducts: 2 marginal (Dallimore & Jackson).
P. resinosa	„ „ 2 marginal 1 median	Resin ducts: marginal (Dallimore & Jackson).
P. sylvestris	Stomata on all faces	Stomata on inner face only (Dallimore & Jackson).
P. tuberculata	Resin ducts: 3 internal 2 median	Resin ducts: median (Dallimore & Jackson).

Explanation of Specific Descriptions.

A detailed description of the leaf section of each species is appended to this report. The species are classified alphabetically in series according to the number of leaves in each dwarf shoot, and to the form of their leaf section.

At the head of each description is given a list of species with similar leaves with which the type might be confused, and a shorter note is added showing the points of difference or distinguishing features in each case. The magnification of all figures is × 62.

In the detailed description each element of the leaf structure is taken in turn from the outer cell layer to the centre. When referring to the stomata the numbers given apply to the average number of stomatic openings situated respectively on the upper face, or upper two faces in triangular or sectoral leaves, and on the lower face, which is the plain surface in plano-convex needles. Thus 3 + 3 + 5 indicates the presence of three stomatic lines on the two upper faces and five on the lower face, or 11 + 15, which shows 11 on the plain face and 15 on the arc of a plano-convex leaf.

The following list explains technical terms used in the text:

Albuminous cells: Parenchymatous cells adjoining and connected to the phloem of the leaf and containing dense cell contents.

Collenchyma: Parenchymatous cells with cellulose walls, usually elongated, forming strands under the epidermis and at thickened angles of the leaf.

Chlorophyll: Green colouring matter present as granules in certain plant cells and characteristic of the mesophyll tissue.

Cuticle: An outer layer of hard thickening produced on the outside epidermal walls.

Dwarf shoot: The needle-bearing shoots of pines composed of two or more needles borne in the axils of scale-like leaves which form the leaf sheath.

Endodermis: A layer of ground tissue bounding the stele and differentiated as a distinct sheath. The much thickened portion of the lateral walls is termed the " endodermal dot."

Epidermis: The surface layer of leaf cells.

Epithelium: A definite layer of cells lining a free surface, especially in botany, an internal surface.

Guard cells: The epidermal cells which line the stomatic passage and which control its opening and shutting by alternate contraction and expansion.

Hypodermis: A layer of one or more rows of cells situated immediately below the epidermis, and usually with more or less thickened walls.

Lumen: The space bounded by the walls of an organ, as the central cavity of a cell.

Mesophyll: Thin-walled assimilating parenchymatous tissue forming the ground tissue of the leaf, the cells of which contain green chlorophyll granules, and in pines have their walls infolded or plicate.

Palisade cells: The outer row of mesophyll cells with deep plicate infoldings at right angles to the leaf surface, and having the appearance of a palisade layer.

Parenchyma: Spongy tissue, the cells of which appear in cross section as of equal dimensions.

Parenchyma rays: Plates of parenchyma cells placed vertically and radially between the cell rows of xylem or phloem in the leaf, and appearing in cross section as medullary rays.

Phloem: Cells of the vascular tissue specialised for the conduction of assimilated food supply in the plant.

Sclerenchyma: Parenchyma tissue in which the walls are specially thickened by the laying down of extra layers of lignin.

Stoma: A pore in the epidermis of the leaf used for the passage of gases between the atmosphere and the inner leaf tissue.

Tracheid: An elongated closed cell of the wood tissue provided with secondary thickening on the walls.

Transfusion tissue: Strands of tracheidal cells of the conjunctive tissue, consisting, in pines, of tracheids with bordered pits.

Vascular bundle: A compact strand of specialised conducting tissue consisting of xylem and phloem separated by a layer of formative tissue or cambium developing both xylem and phloem, together with one or more forms of conjunctive cells.

Water layer: A row of thin-walled hypodermal cells immediately adjoining the epidermis, and apparently containing only water.

KEY TO THE MICROSCOPICAL IDENTIFICATION OF LEAVES OF THE GENUS PINUS.

According to: Character of cross section.
Number and position of resin ducts.
Number and position of stomata.
Nature of hypodermal tissue.

A. *Cross Section—Triangular.*

I.—Resin ducts in twos:

Resin ducts median, stomata on all faces, in pairs - - *P. Montezumae*
„ „ „ „ „ „ „ „ fours - *P. leiophylla*
„ „ peripheral „ „ „ „ „ pairs - *P. Lambertiana*
„ „ „ „ „ „ „ „ fours - *P. flexilis*
„ „ „ „ „ „ two faces only, in pairs - - - *P. strobus*
„ „ „ „ „ „ two faces only, over four (5 + 5) - *P. excelsa*

II.—Resin ducts in threes:

Resin ducts median, stomata on all faces - - - - *P. Torreyana*
„ „ „ and peripheral, stomata on two faces only - - - - - - - - *P. Armandi*

B. *Cross Section—Sector.*

I.—Resin ducts in twos:

Resin ducts median, stomata on all faces, number 15 + 9 + 9 - *P. taeda*
„ „ „ stomata on all faces, number 6 + 3 + 3 - *P. Sabiniana*
„ „ „ stomata on all faces, number 12 + 5 + 5 - *P. Coulteri*
(N.I.)
„ „ „ stomata on all faces, number 9 + 5 + 5 - *P. radiata*
„ „ „ internal number 10 + 4 + 4 - *P. palustris*
„ „ peripheral, stomata on all faces, number 3 + 3 + 3 - *P. canariensis*
„ „ peripheral. stomata on two faces only, number 3 + 3 - *P. aristata*

II.—Resin ducts in threes or fours:

Resin ducts median, with 1 water layer of hypoderm, 4 ducts - - - -	*P. scopulorum*
„ „ „ with 1 pseudo-water layer of hypoderm, 2-3 ducts - - -	*P. rigida*
„ „ „ with no water layer, but 3-5 rows of sclerenchyma - -	*P. ponderosa*
„ „ „ with no water layer, but 1 row of sclerenchyma - -	*P. Jeffreyii*
Resin ducts internal with 1 hypodermal water layer -	*P. caribaea*
„ „ median and internal, with hypodermal water layer - - - -	*P. patula*

III.—Resin ducts five or more:

Resin ducts median, stomata on all faces, number 19-7-7, no water layer - - -	*P. Coulteri* (S.I.)
„ „ „ or internal, stomata on all faces, number 8-5-5, 1 water layer	*P. tuberculata*
„ „ „ and peripheral, stomata on all faces, number 10 + 3 + 3, pseudo water layer - - - - - - - -	*P. yunnanensis*

C. *Cross Section—Semi-circular.*

I.—Resin ducts absent, stomata 7-11, 1 water layer - *P. Murrayana*
„ „ „ „ 6-9, 1 pseudo-water layer - *P. pinea*

I.—Resin ducts absent, stomata 7-11, 1 water layer -	*P. Murrayana*
„ „ „ „ 6-9, 1 pseudo-water layer -	*P. pinea*

II.—Resin ducts two to four:

Resin ducts median, 2, stomata 11 + 15, 1 water layer	*P. echinata*
„ „ „ 2, stomata 9 + 6, 1 or 2 sclerozed hypodermal layers - - -	*P. luchuensis*
„ „ „ 2, stomata under 9 + 6, 2 hypodermal layers - - - - - -	*P. Banksiana*
„ „ „ (and internal), stomata under 15 + 11 - - - - - - - - -	*P. caribaea*
„ „ „ 3, stomata 12 + 8, two hypodermal layers - - - - - - -	*P. Thunbergii*
„ „ „ 3, stomata 11 + 8, 1 water layer, stomata deeply sunken - -	*P. muricata*
„ „ peripheral 2 and median, stomata 7 + 10 -	*P. resinosa*

III.—Resin ducts five and over.

Resin ducts median, 9, stomata 15 + 8 - - - - -	*P. pinaster*
„ „ „ 8-10, stomata 10 + 9 - - - - -	*P. laricio*
„ „ „ 14, stomata 14 + 6 - - - - -	*P. austriaca*
„ „ peripheral, 6, stomata 6 + 3, two rows of sclerenchyma on arc, 1 on base, only 2 resin ducts on upper face	*P. halepensis*
„ „ „ 6-8, stomata 8-8, 1 row of sclerenchyma on all faces - - -	*P. Massoniana*
„ „ „ 7-9, stomata 10-7, no sclerenchyma, but a water layer - - -	*P. densiflora*
„ „ „ 8, stomata 9-9, 1 layer of sclerenchyma, and 1 water layer -	*P. sylvestris*

D. *Section 4-sided.*

Resin ducts peripheral, 3, stomata 4 + 4 on 2 faces only	*P. monticola*

E. *Section Circular.*

Resin ducts, 2, peripheral - - - - - - - - -	*P. monophylla*

SERIES I—Single-needle Pines (leaf section circular).

P. monophylla (Rotorua). (Fig. 4.)

This species has a characteristic section, and is easily distinguished from monophyllous types of *P. sylvestris* and *P. edulis* by its distinct structure.

Leaf Section: Circular, the outline much segmented by stomatic openings.

Epidermis: Circular, irregular, thickened cells.

Stomata: 25-30 evenly distributed around leaf. The guard cells deeply sunken, small, and thickened on inner and part of outer walls; the cells lining the outer passage are also sclerosed, each prolonged into a knob-like projection, and act as outer guard cells; the inner passage bounded by a U-cell.

Hypodermis: 1 row of sclerenchyma.

Mesophyll: 4 or 5 rows of slightly plicate, hexagonal cells, the outer row with palisade infoldings.

Resin ducts: 2 marginal placed opposite the flanks of the vascular bundle; an outer ring of about 15 thickened cells with an inner layer of unthickened lining cells round a large cavity with diameter about one-third of the width of the mesophyll.

Endodermis: Large, regular, circular, unthickened cells.

Vascular strand: Circular, V-B single, in a spreading arc; opposite the protoxylem is a mass of tissue made up of pitted transfusion cells and thick-walled cells with dense contents; opposite the phloem is a group of albuminous cells with cell contents, flanked by pitted transfusion tissue; a few indistinct " rays " traversing xylem and phloem.

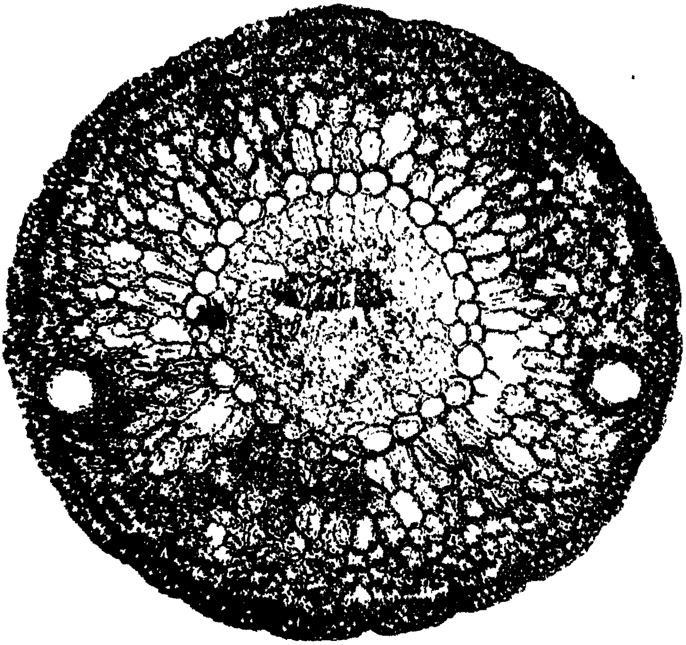


Fig. 4

SERIES II—Two-needle Pines (leaf section semi-circular).

P. austriaca *(P. nigra* var. *austriaca).* (Rotorua.) (Fig. 5.)

Comparative with: *P. laricio,* which cannot be distinguished by any fundamental differences; but has fewer resin ducts, sometimes internal, and few stomatic lines. *P. austriaca* has an uneven, ridged upper surface. *P. densiflora, P. sylvestris,* which have a similar number of peripheral resin ducts.

Leaf section: Semi-circular.

Epidermis: Regular, oblong, much thickened cells with dot lumen.

Stomata: 8 on upper face, 12 on lower face. Guard cells sunk below level of the hypoderm, thickened on inner face; opening urn-shaped, inner air space bounded by U-cell.

Hypodermis: 1 row of regular cubical cells, with thicker walls than in a water layer, and 1 row of sclerosed cells increased at angles and in groups.

Mesophyll: 3 rows of plicate, 5 lobed cells.

Resin ducts: 14 median, arranged around the stele, small, of about 8 slightly thickened outer cells, lined with epithelial cells.

Endodermis: Small, rounded, slightly thickened cells.

Vascular strand: Kidney shaped; vascular bundles 2, separated by thin-walled parenchyma and a narrow band of thickened cells; immediately bounding the phloem is a band, 1 cell thick, of sclerenchyma cells with contents.

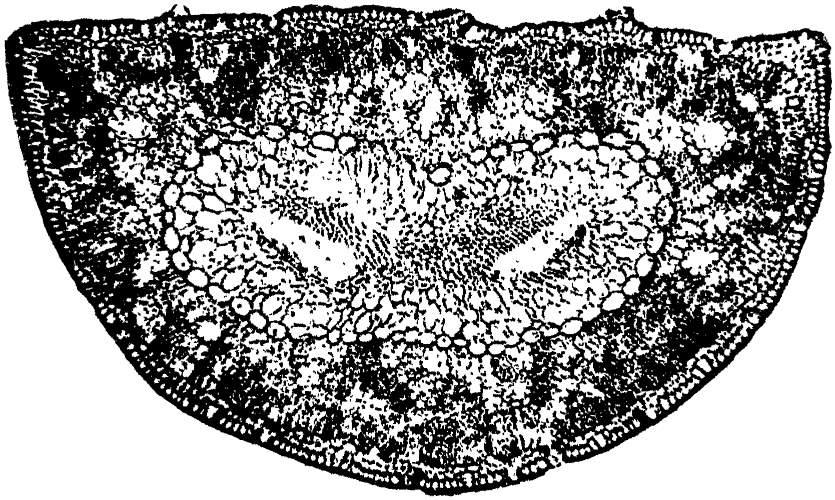


Fig. 5

P. Banksiana. (Fig. 6.)

Comparative with: *P. luchuensis,* which differs definitely in no diagnostic characters, and from which *P. Banksiana* can only be distinguished by its widely separated vascular bundles, and the presence of an indefinite " water layer " of hypodermis.

P. caribaea, which has a greater number of stomatic lines.

P. Thungergii and *P. muricata,* with usually 3 resin ducts.

Leaf section: Semi-circular and elongated.

Epidermis: Regular, cubical, much thickened cells.

Stomata: 6 on upper face, 9 on lower face. Guard cells slightly sunk below hypodermis, sclerosed on both walls; opening bounded by crescent-shaped epidermal cells; inner space bounded by U-cell.

Hypodermis: A pseudo water layer and one row of sclerosed cells much flattened in places, increased at the angles and in scattered groups.

Mesophyll: Two rows increased at corners, of much plicated cells, with distinct palisade infoldings.

Resin ducts: 2 median; large, of 1 row of sclerosed cells.

Endodermis: Elongated, elliptical cells, thickened on outer and lateral walls.

Vascular strand: A flattened ellipse, vascular bundles 2, widely separated by thin-walled parenchyma; on flanks of the phloem are scattered storage cells, and a few pitted transfusion cells are visible; distinct storage " rays " traversing xylem and phloem. N.B.—In many sections examined there were no resin ducts.

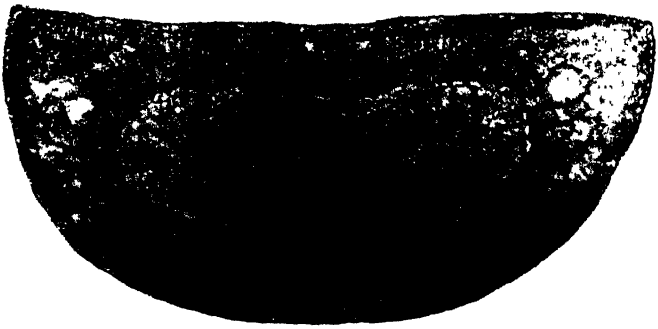


Fig. 6

P. densiflora. (Fig. 7.)

Comparative with: *P. resinosa,* which has only 2 or 4 resin ducts peripheral, and some median.

P. luchuensis, austriaca, muricata, Thunbergii, all of which have median resin ducts.

P. Massoniana, which also has one water layer only.

Leaf section: Semi-circular.

Epidermis: Cubical cells with rounded outer wall and distinct cuticle layer.

Stomata: 7-8 on upper face, 10-14 on lower face; often in pairs close together; not sunken; guard cells sunk below hypoderm; inner chamber bounded by U-cell.

Hypodermis: 1 row of water layer cells.

Mesophyll: 3 rows of plicate, roughly 6 lobed circular cells, with palisade infoldings.

Resin ducts: 10-12 peripheral, 3 on the upper plain face; fairly small, of 7-9 thickened cells, with slight epithelial layer.

Endodermis: Distinct, elliptical cells thickened on outer wall.

Vascular Strand: Elliptical, vascular bundles 2; surrounded by thick-walled parenchyma; on the outer flank of the phloem is a mass of " albuminous " cells with storage cell contents, and outside these a group of transfusion cells.

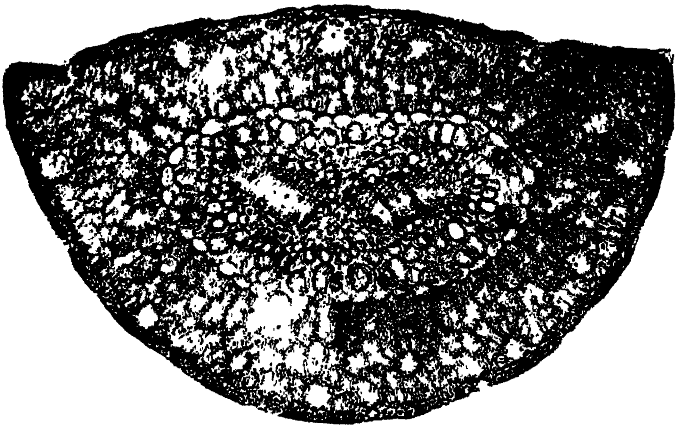


Fig. 7

P. echinata (Rotorua). (Fig. 8.)

Comparative with: *P. Murrayana,* with fewer stomatic lines and vascular bundles widely separated; *P. Banksiana,* with indefinite water layer, fewer stomata, and bundles very widely separated; *P. luchuensis,* with no water layer.

Section: Semi-circular.

Epidermis: Regular, small cells with even outer surface.

Stomata: 11 on upper surface, 15 on lower surface, guard cells only slightly sunk.

Hypodermis: 1 row of regular, thin-walled water cells and an inner, slightly thickened scleroderm layer.

Mesophyll: A distinct palisade layer together with an inner row of plicate parenchyma, increased at angles.

Resin ducts: 2 median, of about 12 thickened cells with an inner epithelial layer of cells; sometimes 1-3 median or internal additional small ducts in the lower mesophyll.

Endodermis: Elliptical, regular, of large cells thickened on the outer and lateral walls.

Vascular strand: Of two vascular bundles, closely placed, with transfusion tissue on the flanks.

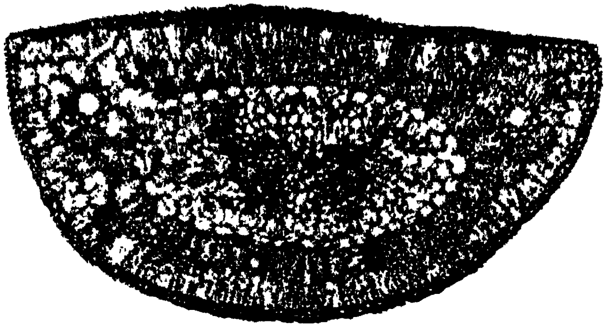


Fig. 8

P. halepensis (Rotorua). (Fig. 9.)

Comparative with : *P. Massoniana,* which has one hypoderm layer only.

P. sylvestris, which has one hypoderm water layer and no sclerosed layer, and with outline much broken by stomata.

P. densiflora, which has usually more resin ducts and has a water layer only.

Leaf section: Semi-circular.

Epidermis: Regular, cubical cells with thickened walls and reduced lumen; much thickened cuticle.

Stomata: 3 on upper face, 6 on lower face. Guard cells much sunk below level of hypodermis, thickened on both faces; opening flanked by the projecting tips of epidermal cells, and bounded inside by U-shaped mesophyll cell.

Hypodermis: 1 row of thin-walled water layer; with a further sclerosed layer along the lower surface.

Mesophyll: Markedly plicate circular cells, with palisade infoldings.

Resin ducts: 6 peripheral, sometimes 1 or 2 median; 2 only on upper face; of about 9 thickened cells, around an epithelial layer.

Endodermis: Round cells, unthickened.

Vascular strand: Elliptical, 2 V-B connected by thickened parenchyma cells; a mass of these also face the protoxylem; a few transfusion cells are scattered on the outer flanks of the bundles; large single thickened parenchyma cells scattered below endodermis. Some " rays " apparent in the phloem.

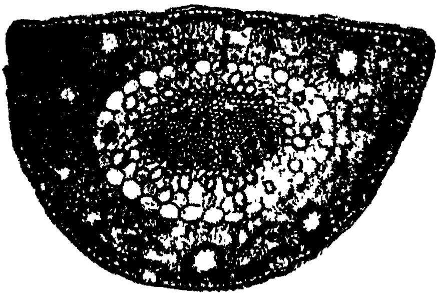


Fig. 9

P. laricio *(P. nigra,* var. *calabrica).* (Fig. 10.)

Comparative with: *P. pinaster,* which has a distinct water layer.

P. caribaea, which has some resin ducts internal, and up to 15 stomata on the lower face.

P. Banksiana, which has 2 resin ducts.

P. Thunbergii, which has 2-3 resin ducts.

P. muricata, which has a water layer, 3 resin ducts, and deeply sunken stomata.

P. Murrayana, which has no resin ducts (in samples examined).

Leaf section: Semi-circular.

Epidermis: Regular, large, narrowly oblong cells, much thickened.

Stomata: 9 on upper surface, 8 on lower surface. The cup-shaped narrow openings bounded by the elongated epidermal cells; guard cells sunk below hypodermis, fully sclerosed.

Hypodermis: 1-2 rows of thickened cells, a single row only on the lower surface.

Resin ducts: 8-10 median, sometimes 1 or 2 internal; usually of 2 rows of thickened cells, not sclerosed.

Endodermis: Very regular, elliptical cells, thickened on lateral walls.

Vascular strand: Flatly elliptical, vascular bundles 2, surrounded by large-celled parenchyma. Subtending the phloem is a band of collenchymatous cells. No " rays " visible.

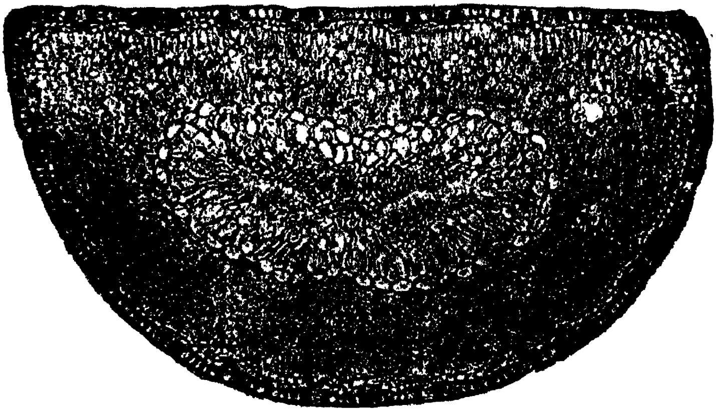


Fig. 10

P. luchuensis. (Fig. 11.)

Comparative with: *P. Banksiana,* with widely separated vascular bundles and an indefinite water layer.

P. caribaea (2-needle), with many (15-11) lines of stomata.

P. Thunbergii and *P. muricata,* with usually 3 resin ducts and the latter with deeply divided outline.

Leaf section: Semi-circular.

Epidermis: Regular, much thickened cubic cells, with lumen reduced to a dot; outer cuticle distinct.

Stomata: 6 on upper face, 9 on lower face. Deeply sunk, opening bounded by roughly triangular epidermal cells, inner opening bounded by U-cell.

Hypodermis: 2 rows of thickened, irregular cells.

Mesophyll: 2 rows of plicate cells, showing palisade infoldings.

Resin ducts: 2 median, of 1 or 2 rows of slightly thickened cells.

Endodermis: Large celled, thickened on lateral walls.

Vascular strand: Elliptical, vascular bundles 2, spreading; large cells of sclerenchyma scattered opposite the phloem.

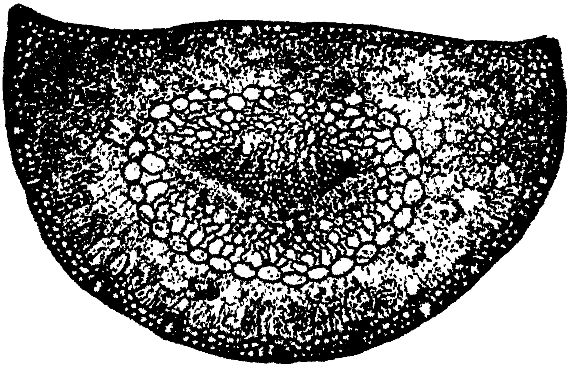


Fig. 11

P. Massoniana. (Fig. 12.)

Comparative with: *P. halepensis* and *P. densiflora,* but differs from the former in having 1 row of sclerosed hypoderm cells on all faces.

Leaf section: Semi-circular.

Epidermis: Regular, cubical cells; all walls much thickened, giving a dot lumen; outline even.

Stomata: 7-8 on upper face, 8-10 on lower face.

Hypodermis: 1 or 2 rows of sclerosed hypoderm cells increased at angles.

Mesophyll: Much plicated, hexagonal cells with palisade formation on all surfaces.

Resin ducts: 6-8 peripheral, on both surfaces, each duct of 1 row of thickened cells surrounding a large cavity approximately 1-16th of the plain face length.

Endodermis: Oval cells with thickened outer and adjacent walls, not very distinct from inner parenchyma.

Vascular strand: Elliptical; V-B 2, a few transfusion rays through xylem and phloem, scattered thickened parenchyma cells around the bundles.

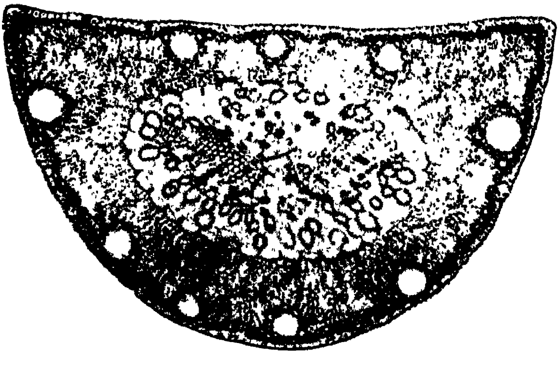


Fig. 12

P. muricata (Rotorua). (Fig. 13.)

Comparative with: *P. laricio,* which has no water layer.
P. pinaster, with 9 resin ducts.
P. Murrayana, which has no resin ducts and the two vascular bundles widely separated in the stele.
P. luchuensis, which has no distinct water layer.
P. austriaca, which has 14 resin ducts.
P. pinea, with no resin ducts and no water layer.

Leaf section: Semi-circular.

Epidermis: Deeply broken by stomata; regular, almost cubical cells rounded on outer edge and much thickened.

Stomata: 8 on upper face, 11-12 on lower face. Large, sunk below hypodermis; the wide opening bounded by narrow epidermal cells; guard cells completely thickened, inner air space bounded by a U-cell.

Hypodermis: 1 " water layer " and one sclerosed layer increased at angles and sometimes in groups.

Mesophyll: 2 rows of deeply plicate circular cells, with palisade infoldings on either face.

Resin ducts: 2 median; of 10 sclerosed cells.

Endodermis: Large oval cells.

Vascular strand: Elliptical, vascular bundles 2, surrounded by thin-walled parenchyma; a little transfusion tissue on flanks; distinct " rays " visible.

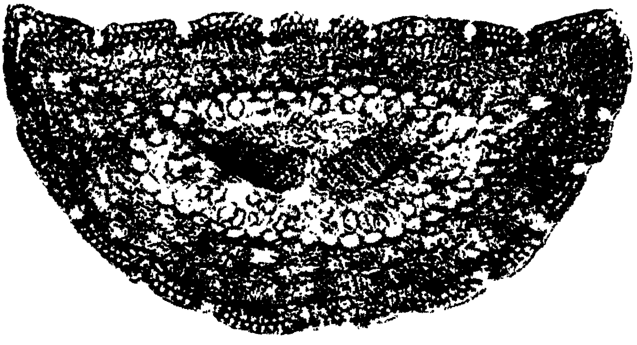


Fig. 13

P. Murrayana *(P. contorta* var. *latifolia).* (Fig. 14.)

Comparative with: *P. laricio,* which differs in having many (8-10) resin ducts.
P. Banksiana, which has a water layer.
P. luchuensis, with V-B not widely apart.
P. austriaca, with many (14) resin ducts.
P. pinea, of greater size of leaf section.

Leaf section: Semi-circular.

Epidermis: Regular, almost cubical, thickened cells, rounded on outer edge.

Stomata: 7 on upper surface, 11 on lower surface. Guard cells slightly sunk.

Hypodermis: 1 row of water layer cells, and 1 row, increased in places, of rounded sclerenchyma.

Mesophyll: 2 rows of shortly plicate circular cells.

Resin ducts: Nil.

Endodermis: Regular, elliptical cells, thickened on outer and lateral walls.

Vascular strand: Flattened elliptical, vascular bundles 2, small, surrounded by and widely separated by large, thin-walled parenchyma.

N.B.—Dallimore and Jackson, Elwes and Henry, and Mathews give this species as possessing median resin ducts.

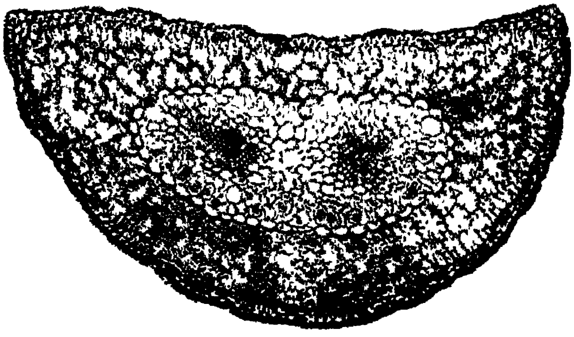


Fig. 14

P. pinaster (Rot. 2). (Fig. 15.)

Comparative with: *P. laricio*, with no water layer.
P. austriaca, with no water layer.
P. pinea, with few or no resin ducts, and no parenchyma " rays."

Section: Semi-circular.

Epidermis: Regular, cubical, thickened cells with dot lumen.

Stomata: 7 on upper face, 15 on lower face. Deeply sunk; guard cells below level of the hypodermis. Tubular opening is bounded by an elongated epidermal cell which is " beaked " at the inner margin, restricting the stomatic opening; inner air space bounded by a U-cell.

Hypodermis: 1 " water layer " of large, somewhat irregularly shaped cells, with one or two rows of large, irregularly shaped sclerenchyma cells interrupted at the stomata, increased at angles and with cell walls much thickened.

Mesophyll: 2 or 3 rows of deeply plicate, roughly 4-6 lobed, square parenchyma cells.

Resin ducts: 9 median, placed around arc on the lower face only; of 1 row of 9 sclerosed cells.

Endodermis: Large, almost circular cells, scarcely thickened.

Vascular strand: Flattened elliptical; vascular bundles 2, large; a row of thickened parenchyma bounds the phloem masses and extends between the bundles. A mass of distinct albuminous cells flanks the phloem masses adjoined by the transfusion tissue. " Rays " distinct in xylem phloem.

NOTE.—This specimen differs from other types examined, which have (i) only 2 resin ducts; (ii) 20 ducts; the leaves of these types have no water layer.

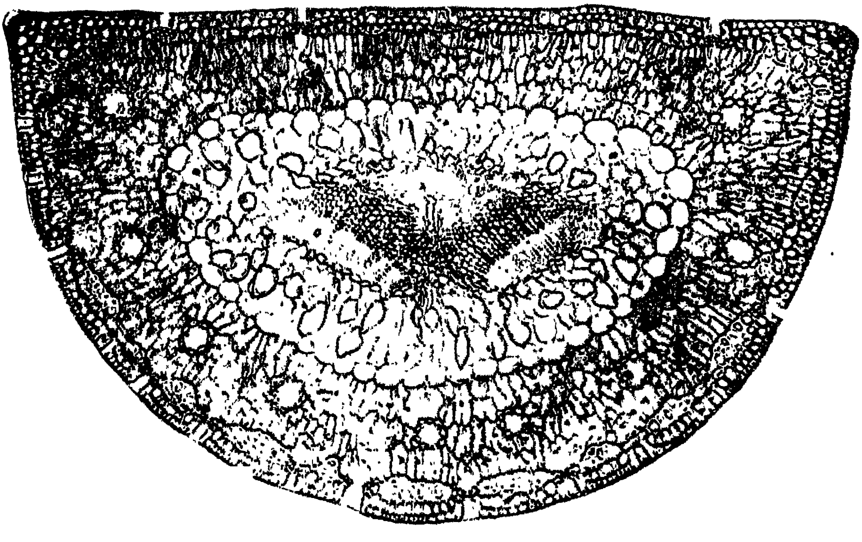


Fig. 15

P. pinea (Rotoura). (Fig. 16.)

Comparative with: *P. pinaster,* which has resin ducts and a distinct water layer, with hypodermal sclerenchyma projecting into the mesophyll between deeply sunk stomata.

P. Murrayana, with a distinct water layer and greater number of stomata.

Leaf section: Semi-circular.

Epidermis: Even, large, much thickened cells; cuticle thin.

Stomata: 6 on upper face, 9 on lower face. Guard cells sunk below hypodermis, partly thickened.

Hypodermis: 2 rows of thickened cells, the outer layer having the appearance of a water layer, but with thickened walls, the inner row sclerosed.

Mesophyll: 3 rows of plicate, 6 lobed cells, with outer deep palisade infoldings.

Resin ducts: Nil.

Endodermis: Circular cells not distinct from inner parenchyma, slightly thickened on outer walls.

Vascular strand: Elongated plano-convex, 2, small vascular bundles, surrounded by small celled parenchyma; xylem very regular, flanked on outer edges by transfusion cells; no rays visible.

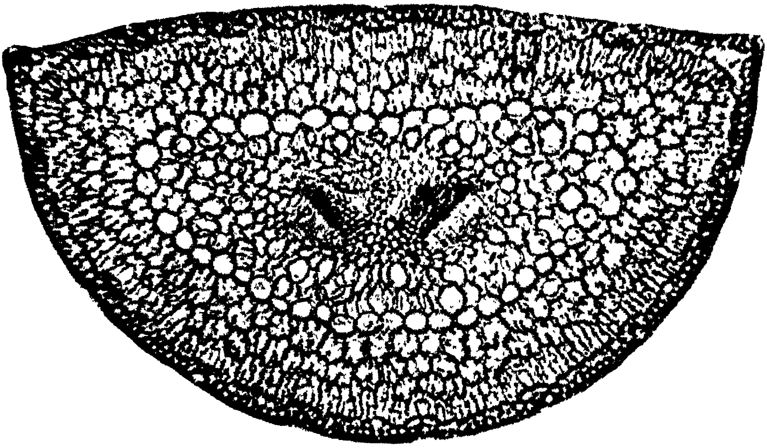


Fig. 16

P. resinosa. (Fig. 17.)

Comparative with: *P. luchuensis*, which has only median resin ducts, and no water layer.

P. halepensis and *P. Massoniana*, in both of which the resin ducts are bounded by 1 row of cells only.

Leaf section: Semi-circular.

Epidermis: Cubical, even cells with a dot lumen.

Stomata: 7 on upper face, 10 on lower face. Slightly sunk inner chamber bounded by U-cell.

Hypodermis: One row of pseudo water layer cells.

Mesophyll: 3-4 rows of roughly 6 lobed plicate cells, wth slight palisade infoldings.

Resin ducts: 2 median, 4 peripheral, the latter fairly large of 12 thickened cells in a double row; those median are smaller and apparently rudimentary.

Endodermis: Of flattened, elliptical cells, thickened on outer walls.

Vascular strand: Elliptical, vascular bundles 2, surrounded by thin-walled parenchyma; a little transfusion tissue on flanks; no visible rays.

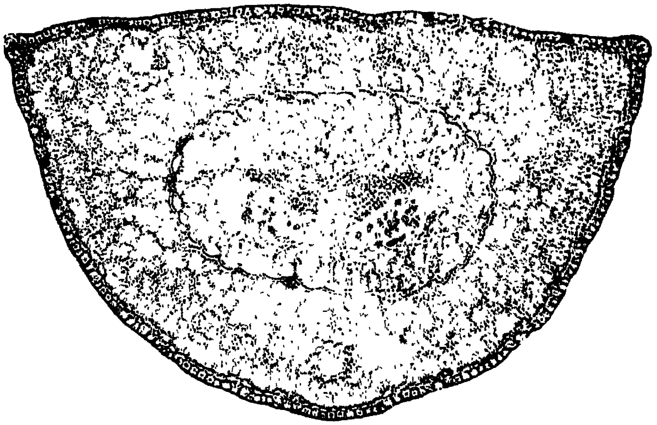


Fig 17

P. sylvestris (Rotorua). (Fig. 18.)

Comparative with: *P. halepensis,* which has 2 hypoderm layers.
P. resinosa, which has fewer resin canals—2-4 peripheral and sometimes 2 median.

Leaf section: Semi-circular.

Epidermis: Outline broadly crenate, of very regular, narrowly oblong cells with reduced lumen.

Stomata: 9-12 on lower face, 8 on upper face. The urn-shaped opening bounded by projecting lips of epidermal cells; guard cells sunk below the hypodermal layer.

Hypodermis: A water layer of flattened, thin-walled cells and one row sclerosed cells.

Mesophyll: Shortly plicate, hexagonal cells, with granular cell contents.

Resin ducts: 8 peripheral, of 1 row of 8-9 irregular spherical, much thickened cells with lumen much reduced.

Endodermis: Regular, elliptical, small cells, laterally thickened.

Vascular strand: Elliptical flattened; vascular bundles 2, small, separated by a mass of thickened parenchyma cells; a band of collenchymatous cells crosses the stele facing the phloem.

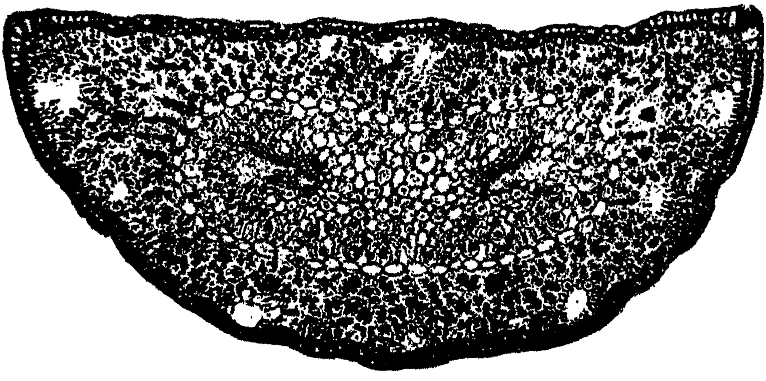


Fig. 18

P. Thunbergii. (Fig. 19.)

Comparative with: *P. Massoniana*, with 6-8 peripheral ducts.

P. halepensis, with 6-7 ducts, and stomata in lines of 6 + 3.

P. muricata, with deeply sunken stomata and hypodermis in groups.

P. luchuensis, with 2 layers of scleroderm hypodermis.

P. densiflora, with peripheral resin ducts.

Leaf section: Semi-circular.

Epidermis: Regular, thickened cells with dot lumen.

Stomata: 8 on upper surface, 12 on lower surface. Guard cells sunk below hypodermis; crescent-shaped epidermal cells bounding the wide opening.

Hypodermis: 1 row of small thin-walled cells next to epidermis, together with 1 row, doubled in places, of larger irregularly shaped sclerosed cells.

Mesophyll: Slightly plicate 5-6 lobed cells, with palisade infoldings on both faces.

Resin canals: 2 median placed at the angles; of 1 row of sclerosed cells, lined with epithelium.

Endodermis: Regular, almost spherical cells.

Vascular strand: Elliptical, vascular bundles 2, surrounded by thin-walled parenchyma.

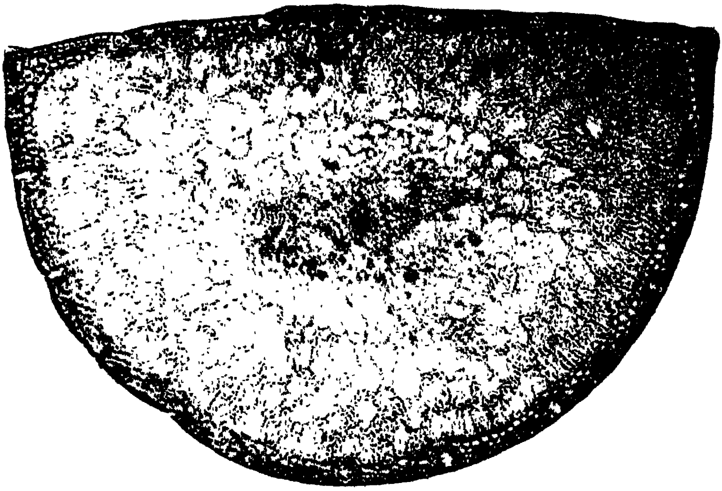


Fig. 19

SERIES III—Three-needle Pines (leaf section, sector).

P. canariensis. (Fig. 20.)

Comparative with: *P. patula,* with internal and median ducts.
P. Sabiniana, which has median ducts.
P. aristata, which has a characteristic non-plicate mesophyll.

Leaf section: Sector.

Epidermis: Even, regular, cubical cells with dot lumen.

Stomata: 3 + 3 on upper face, 4 to 6 on lower face. Guard cells sunk below hypodermis, outer passage urn-shaped.

Hypodermis: 2 or 3 rows of sclerosed cells, increased between stomata to groups of cells projecting into the mesophyll.

Mesophyll: 2 rows of plicate, hexagonal cells, the outer row deeply infolded.

Resin ducts: 2 marginal; of about 9 sclerosed cells surrounding an epithelial layer.

Endodermis: Circular, large, unthickened cells.

Vascular strand: Roughly triangular; V-B 2, large, an arc of thickened parenchyma subtending the bundles, a few " rays " traversing xylem and phloem.

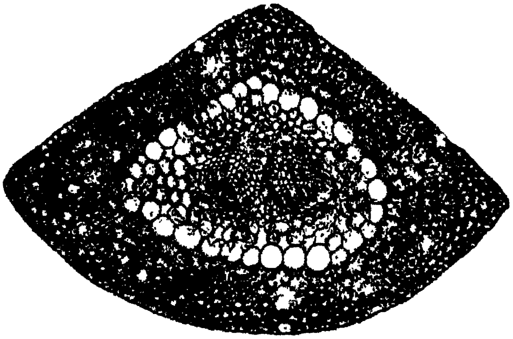


Fig. 20

P. caribaea. (Figs. 21, 22.)

Comparative with: *P. Banksiana,* which has a sclerosed layer and stomata in lines of 6 and 9.

Leaf section: Semi-circular or a sector.

Epidermis: Regular, square, much thickened, with dot lumen.

Stomata: 5 + 5 on each upper face, 12 on lower. Guard cells sunk below hypodermis.

Hypodermis: A row of regular thin-walled cells or water layer, in places strengthened by sclerenchyma cells.

Mesophyll: 2 rows of deeply plicate 5 lobed cells.

Resin ducts: 4 internal; of 1 row of 8 cells thickened, but not sclerosed. Sometimes 2 median ducts.

Endodermis: Irregular, almost spherical, cells with outer wall thickened.

Vascular strand: Elongated elliptical; vascular bundles 2; with transfusion tissue on the flanks, surrounded by large-celled parenchyma; " rays " visible.

N.B.—In leaves of 3-needle bundles, the two vascular bundles are almost in contact.

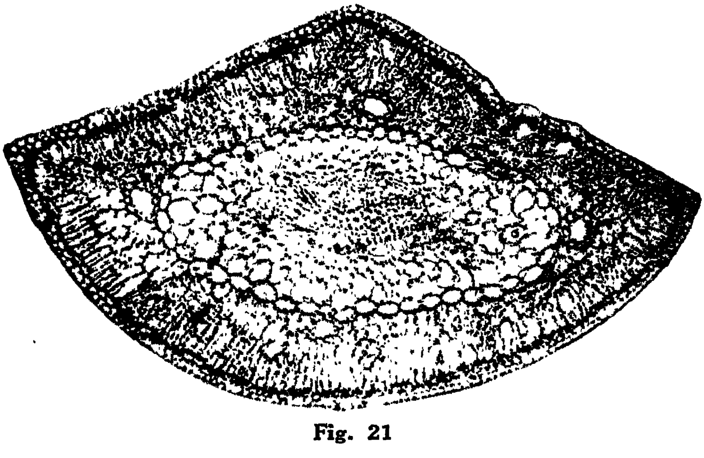
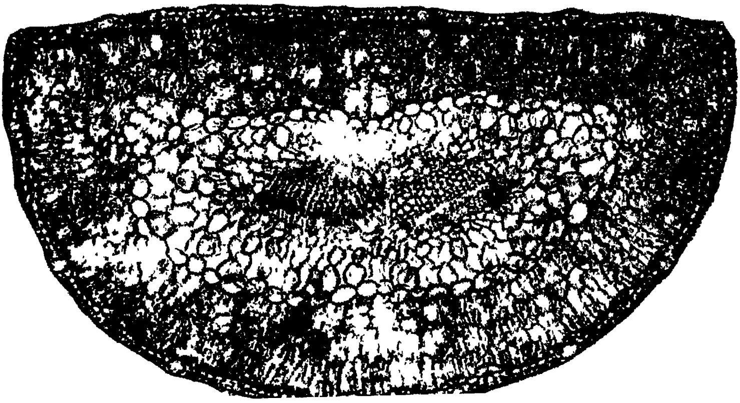


Fig. 21



P. Coulteri (Rotorua). (Fig. 23.)

Comparative with: *P. rigida* and *P. palustris.* This species is distinguished by the greater size of its leaf section and the large proportion of sclerosed hypoderm cells.

Leaf section: Sector.

Epidermis: Regular, square, thickened cells, with dot lumen.

Stomata: 12 + 5 + 5, on all faces; guard cells sunk below epidermal layer, thickened on both walls.

Hypodermis: In groups of 3-4 rows thick projecting into the mesophyll between the stomata; of sclerosed cells, increased at angles.

Mesophyll: Plicate, 6 lobed cells.

Resin ducts: 2 or 4 median, placed at angles and in centre of the lower face; of 1 row of thickened small cells, lined by several broken rows of epithelia.

Endodermis: Regular, elliptical cells with thickened outer and lateral walls.

Vascular strand: Elliptical, extensive, 2-3 vascular bundles, surrounded by thin-walled parenchyma, and subtended on the upper face by a T-shaped mass of thickened sclerenchyma tissue.

N.B.—In South Island specimens, endodermis has lateral walls only thickened, and V.B. is triple-branched.

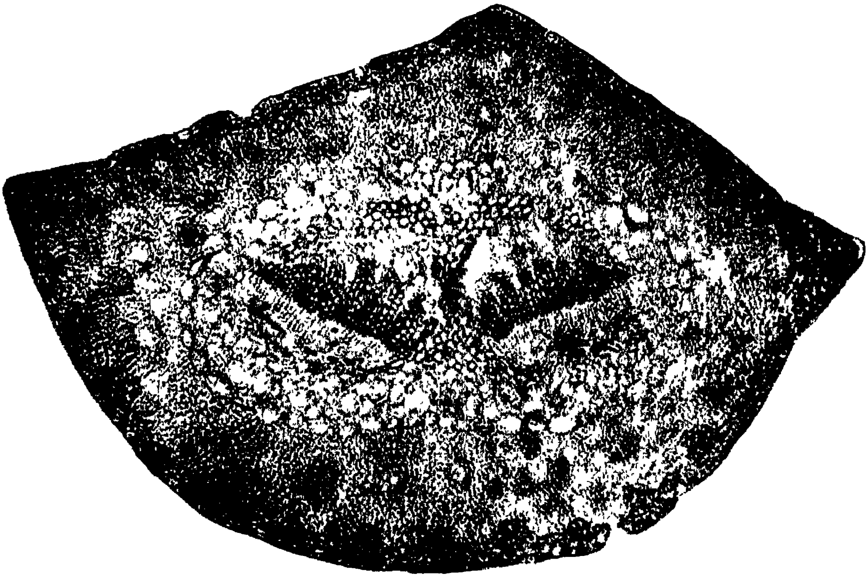


Fig. 23

P. leiophylla (Rotorua). (Fig. 24.)

Comparative with: *P. Montezumae,* which has a distinct schleroderm layer in the hypodermis.

P. excelsa and *P. strobus,* which have peripheral ducts.

P. Armandi, which has stomata on 2 faces only.

Leaf section: Triangular.

Epidermis: Flattened, ovate cells, with much thickened walls.

Stomata: 4 + 4 on upper face, 4 on lower. Guard cells slightly sunken, large, thickened on both faces.

Hypodermis: 1 row of unthickened cells, increased at angles and occasionally by several thick-walled cells.

Mesophyll: 2 rows of slightly plicate cells, with palisade infolding on all faces.

Resin ducts: 2 median; of 2 rows of large unthickened cells surrounding a small cavity.

Endodermis: Elliptical cells larger than and distinct from the inside parenchyma, thickened on outer walls.

Vascular strand: Circular; 2 V-B surrounded by thin-walled parenchyma, a line of thickened cells joining the bundles; some albuminous cells against the phloem.

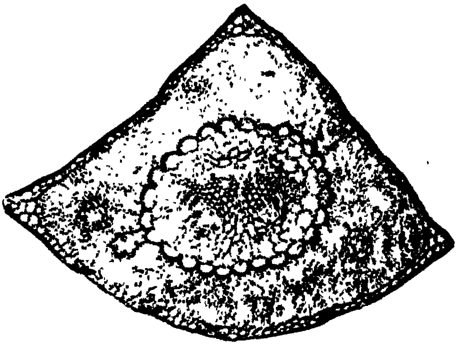


Fig. 24

P. palustris (Rotorua). (Fig. 25.)

Comparative with: *P. caribaea,* which has occasional median ducts and a distinct water layer, with no sclerenchyma.

P. tuberculata, with additional median ducts, and which differs also in having a water layer.

Leaf section: A sector.

Epidermis: Even, cubical cells with dot lumen.

Stomata: 3 + 4 on upper face, 10 on lower. Pores not sunk, guard cells sunk to the level of hypoderm.

Hypodermis: 2 rows irregularly increased to 3 rows of sclerosed cells.

Mesophyll: 2 rows of slightly plicate 4 lobed cells without a palisade formation.

Resin ducts: 2 internal; of an outer row of 12 somewhat thickened cells with an inner row of 9 similar cells, cavity small.

Endodermis: Regular, distinct, elliptical cells, thickened on lateral walls.

Vascular strand: Elliptical, 2 vascular bundles, spreading; a little transfusion tissue present; " rays " visible in xylem. The tissue opposite the protoxylem appears spongy, and constantly breaks apart, leaving large air spaces.

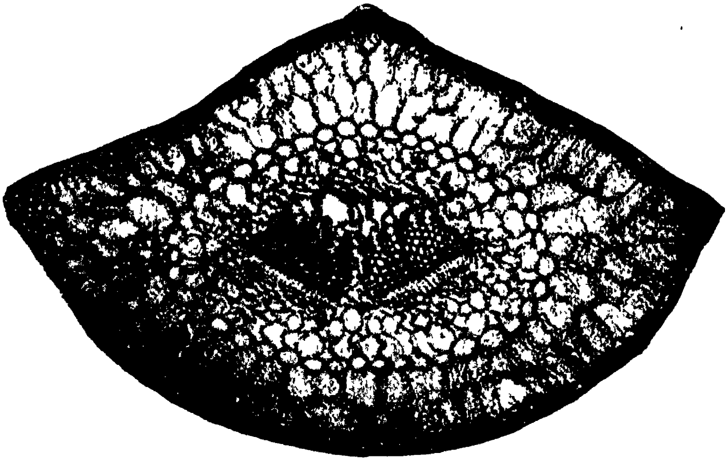


Fig. 25

P. patula. (Fig. 26.)

Comparative with: *P. canariensis,* which has marginal ducts.

Leaf section: A sector.

Epidermis: Much thickened elliptical cells.

Stomata: 3+ 3 on upper face, 6 on lower face.

Hypodermis: 1 layer of water cells and an inner, slightly thicker walled, but unsclerosed layer.

Mesophyll: 2 rows of plicate, 4 lobed cells, with palisade infoldings.

Resin ducts: 2 median and 2 internal, the former of about 10 cells round a large cavity, the internal ducts smaller.

Endodermis: Large, almost spherical cells, thickened on the outer and lateral walls.

Vascular strand: Slightly elliptical; V-B 2, surrounded by thin-walled parenchyma, with a mass of albuminous cells opposite the phloem, "rays" traversing the phloem.

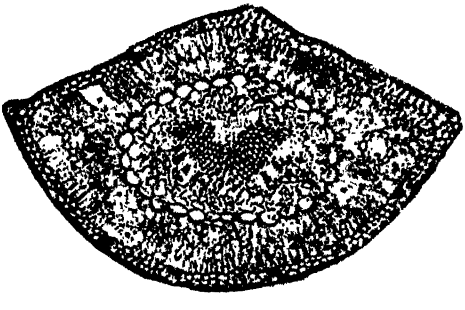


Fig. 26

P. ponderosa (Botanical Gardens, Wellington). (Fig. 27.)

This species closely resembles *P. Jeffreyi*, but in the latter there is no distinct water layer, and only 1 or 2 rows of sclerosed cells.

It differs from *P. scopulorum* in having no water layer in the hypodermis.

No definite character distinguishes this section from that of *P. rigida*.

Section: Sector.

Epidermis: Regular, cubical cells with dot lumen and distinctly thickened cuticle.

Stomata: 3 + 3 on upper face, 8 on lower face. Guard cells deeply sunk to lowest layer of hypodermis; entrance tube bounded by crescent-shaped epidermal cells, and opening at the outer level of the epidermal layer.

Hypodermis: 4-5 rows of irregularly shaped sclerenchyma cells.

Mesophyll: 3 rows of plicate, hexagonal cells.

Resin canals: 3 median placed at the angles; about 25 sclerosed cells in a double row around the epithelial layer.

Endodermis: Regular, elliptical, thickened on outer and lateral walls.

Vascular strand: Elliptical, large; vascular bundles 2, connected on their lower sides by a narrow band of thickened cells, while a band of sclerosed cells borders the thin-walled parenchyma adjoining the xylem. A mass of " albuminous " tissue flanks the bundles and adjoins the outer transfusion tissue. Several " rays " are visible traversing xylem and phloem.

N.B.—The macroscopical characters of this tree were similar to type *P. Jeffreyi*.

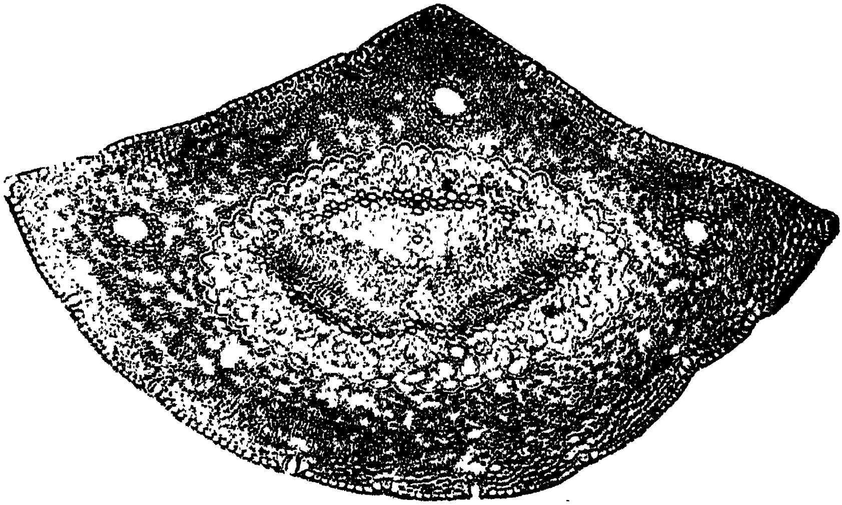


Fig. 27

P. Jeffreyi (Rotorua). (Fig. 28.)

Comparative with: *P. ponderosa* and *P. scopulorum,* the former differs in having 3 to 5 rows of sclerosed hypodermal layer and the latter differs in its distinct water layer.

P. Sabiniana, which has no water layer but 2-3 rows of sclerosed hypodermis.

Leaf section: Sector.

Epidermis: Regular, cubical cells, cuticle thick, outline widely crenated.

Stomata: 5 + 6 on upper faces, 8 on lower. Guard cells sunken, thickened on both faces.

Hypodermis: 2 rows of thickened but not sclerosed cells, the outer row on the upper faces, with thinner walls.

Mesophyll: 2 to 3 rows of plicate, 5 or 6 lobed cells.

Resin ducts: 3 median; of about 12 outer thickened cells, with a disintegrating epithelial lining.

Endodermis: Elliptical cells, thickened on outer wall.

Vascular strand: Flattened, elliptical V-B 2, spreading; a mass of sclerenchyma fronts the lower face of the bundles, which are joined by a line of thickened tissue on the upper face; much transfusion tissue adjoins the vascular tissue.

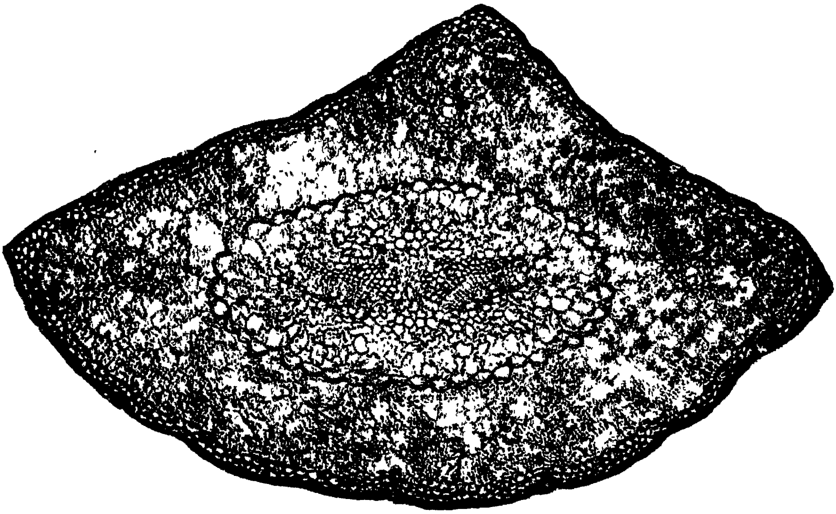


Fig. 28

P. scopulorum (Rotorua). (Fig. 29.)

Comparative with: *P. ponderosa* and *P. Jeffreyi,* from which it differs in its distinct water layer.
P. Sabiniana, which has no water layer.
P. rigida, with small resin ducts.

Leaf section: A sector.

Epidermis: Regular, cubical cells.

Stomata: 5 + 5 on upper faces, 8 on lower face. The cells bounding the pore are slightly sunk below the surface, and cause a wide crenation of the leaf outline. Guard cells sunk to level of hypodermis.

Hypodermis: 1 distinct water layer and 2 rows of sclerenchyma, increased to 3 or 4 in the groups of the lower face.

Mesophyll: 3 rows of plicate cells with palisade infoldings.

Resin ducts: 3 or 4 median; of 1 row of 13-15 thickened cells.

Endodermis: Large, almost circular cells, thickened on the outer wall.

Vascular strand: Elliptical, with 2 vascular bundles surrounded by thin-walled parenchyma, except for an arc of thickened cells subtending the xylem; some transfusion tissue flanks the bundles.

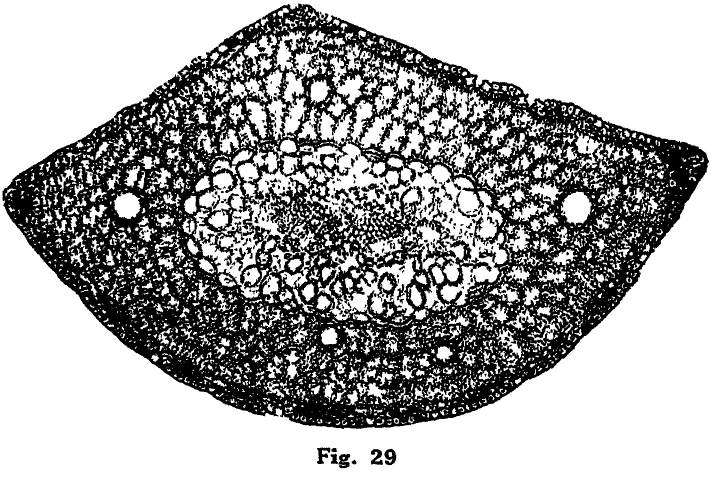


Fig. 29

P. radiata (Fig. 30.)

Comparative with: *P. halepensis*, which has 6 peripheral resin ducts and 1 row of sclerosed hypodermis.

Leaf section: A sector, occasionally semi-circular, margin crenate, interrupted by stomata.

Epidermis: Regular, uniform, square cells with thickened walls and dot lumen.

Stomata: 4-6 on each upper face, 7-10 on lower face. Deeply sunken, of characteristic shape, with the outer bordering pair of epidermal cells each prolonged into a sharp beak enclosing an outer stomatal space; the inner guard cells thickened on both outer and inner walls, and the inner air space bounded by a U-cell of mesophyll tissue.

Hypodermis: 1 layer of thin-walled pseudo-water layer cells together with 2 rows of regular sclerosed cells.

Mesophyll: A palisade layer with 2 or 3 inner rows of plicate cells.

Resin ducts: Usually 2 median, but frequently lacking; duct consists of 1 row of 10 cells with unthickened walls and an inner row of secreting cells.

Endodermis: Regular large elliptical cells thickened on outer and lateral walls.

Vascular strand: Large, elliptical; 2 vascular bundles, surrounded, except on the polar extremities, by thickened parenchyma; between this layer and the endodermis is thin-walled large-celled parenchyma; several " rays " visible in xylem and phloem.

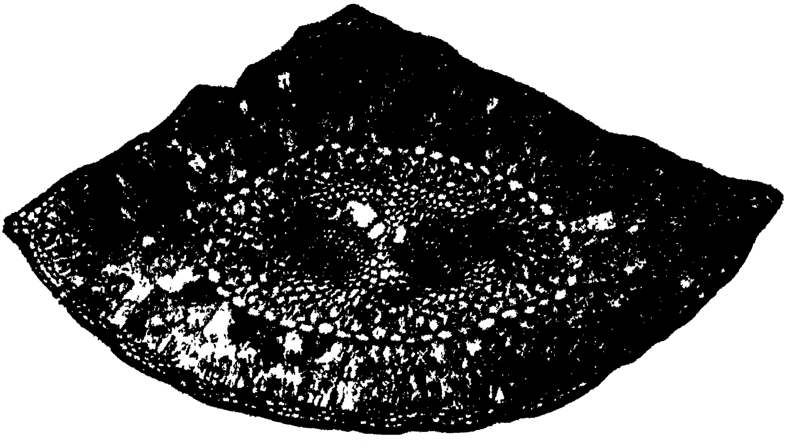


Fig. 30

P. rigida. (Fig. 31.)

Comparative with: *P. ponderosa* and *P. Jeffreyi*, which have no water layer, and with *P. scopulorum*, which has similar structure but a smaller vascular strand.

Leaf section: Sector.

Epidermis: Cubical, regular cells.

Stomata: 7 + 7 on upper faces, 9 on lower. Openings not sunk, guard cells slightly sunk, thickened on both faces, inner pore bounded by U-cell.

Hypodermis: 3 rows of sclerosed cells, the outer row of small, thinner-walled cells, but not a distinct water layer.

Mesophyll: 2 rows of 5-7 lobed plicate cells, the outer walls with palisade infoldings.

Resin ducts: 2 or 3 median; small, of 9 thickened cells with inner epithelial layer.

Endodermis: Regular, distinct, many elliptical cells, thickened on outer and lateral walls.

Vascular strand: Elliptical, large, lined with regular thin-walled parenchyma; vascular bundles 2, spreading; xylem regular, with transfusion tissue on flanks, phloem flanked by distinct masses of albuminous cells; no " rays " visible.

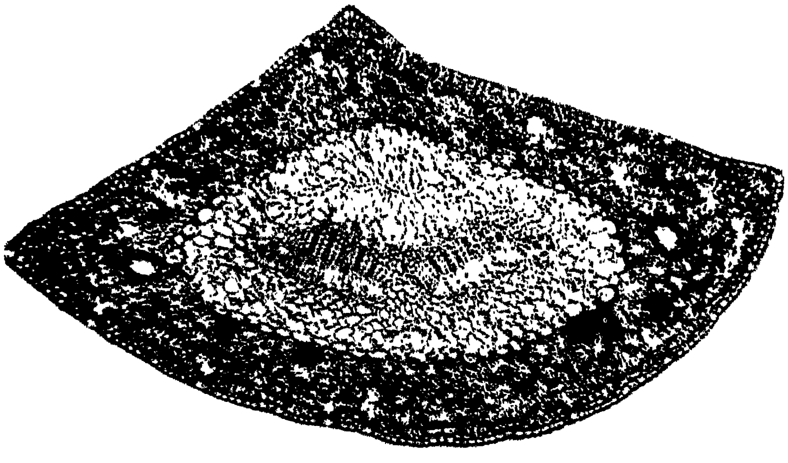


Fig. 31

P. Sabiniana. (Fig. 32.)

Comparative with: *P. canariensis,* with peripheral resin ducts.

P. yunnanensis, with over 5 resin ducts, peripheral.

P. patula, with sometimes internal ducts, and a much smaller leaf section.

P. palustris, with internal resin ducts.

Leaf section: Sector.

Epidermis: Outline widely crenate; of regular, square, much thickened cells.

Stomata: 4 + 4 on upper faces, 7 on lower face. Guard cells slightly sunk, thickened on inner and part of outer wall.

Hypodermis: 2-3 layers of hexagonal, sclerosed cells.

Mesophyll: Large, slightly plicate.

Resin ducts: 2, median, placed at angles; of 2 or more rows of thickened cells surrounding an epithelial layer.

Endodermis: Regular, elliptical cells with laterally thickened walls.

Vascular strand: Reniform; 2 V-B connected by thin-walled parenchyma; an arc of thickened cells adjoins the phloem.

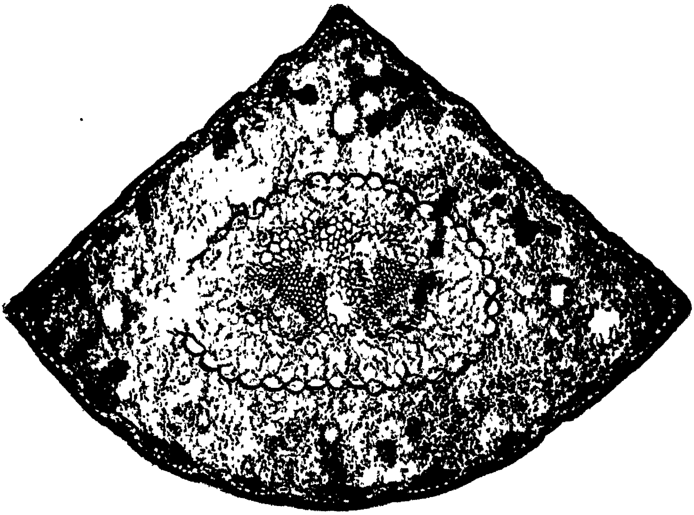


Fig. 32

P. taeda (Rotorua). (Fig. 33.)

Comparative with: *P. leiophylla* and *P. Lambertiana*, which have no sclerosed hypodermal layer.

P. radiata, which is larger, with characteristic stomata and only a pseudo-water layer.

Leaf section: A sector.

Epidermis: Regular, much thickened cells.

Stomata: 4-9 + 4-9 on upper faces, 9-15 on lower face. Slightly sunk; guard cells thickened on both walls.

Hypodermis: 1 row of water layer cells and 1 of irregular sclerosed cells, increased at angles.

Mesophyll: Slightly plicate, circular cells, slight palisade infoldings.

Resin ducts: 2 median; outer layer of 12 slightly thickened cells with epithelial lining.

Endodermis: Regular, large celled; with outer and laterally thickened walls.

Vascular strand: Cordate; vascular bundles 2, placed close together; parenchyma thin-walled, bundles flanked by transfusion tissue; distinct " rays " present.

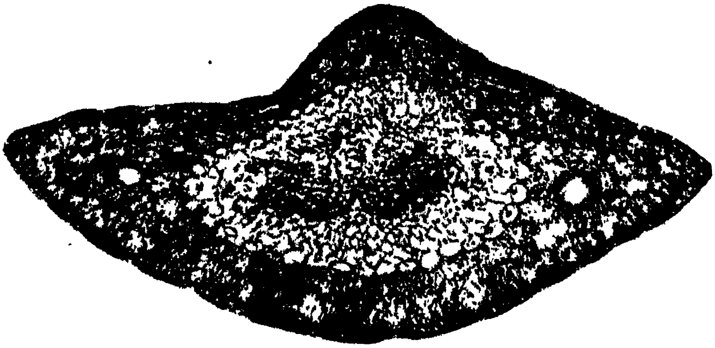


Fig. 33

P. tuberculata (Rotorua). (Fig. 34.)

Comparative with: *P. radiata*, which differs in having extra resin ducts peripheral and fewer stomata.

P. palustris, with no water layer.

P. canariensis, without a water layer.

P. caribaea, with no scherenchyma layer.

P. yunnanensis, which differs in having many (6), marginal ducts, an ill-defined water layer, and only 1 row of sclerosed hypoderm.

Leaf section: Sector.

Epidermis: Regular, cubical, much thickened cells.

Stomata: 5 + 5 on upper face, 8 on lower face. Guard cells sunk, partly thickened on both faces; the bounding epidermal cells large at the base.

Hypodermis: A distinct water layer, bounded on the inner side by 1, increased occasionally to 2, rows of sclerenchyma.

Mesophyll: 2 rows of deeply plicate, 8 lobed cells; marked palisade infoldings.

Resin ducts: 2 median and 2 internal; of an outer row of about 10 unthickened cells and an inner row of 5-6; the ducts are often all median.

Endodermis: Large, elliptical, scarcely thickened cells, but thickened on lateral walls with a distinct endodermal dot.

Vascular strand: Elliptical; vascular bundles 2, closely placed, and surrounded by much unthickened parenchyma; a mass of transfusion tissue on either flank of the bundles; no " rays " present.

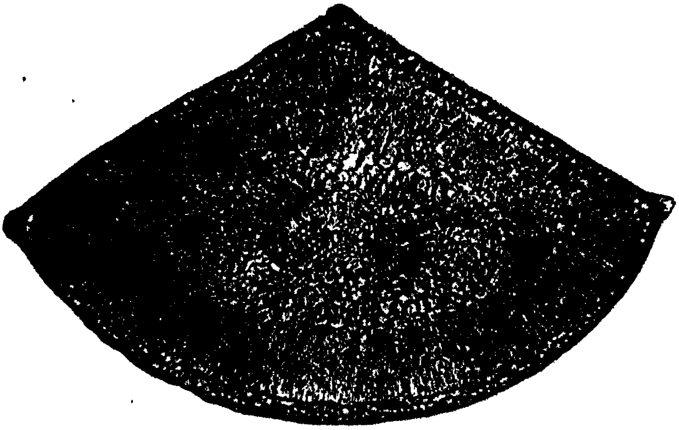


Fig 34

P. yunnanensis. (Fig. 35.)

Comparative with: *P. tuberculata,* with median and internal ducts.

P. radiata, which has only median ducts and several hypodermal layers.

P. canariensis, with schlerenchyma in groups, stomata in threes.

Leaf section: A sector.

Epidermis: Regular, oblong cells giving an even, unbroken outline.

Stomata: 3 + 3 on upper face; 11 or 12 on lower face. Guard cells slightly sunk, thickened on both faces.

Hypodermis: 1 layer of small-sized pseudo water cells and an inner row of larger, slightly thickened cells, slightly increased at angles.

Mesophyll: 2 rows of many lobed plicated cells.

Resin ducts: 6 peripheral, of which 4 are placed on the lower face and 2 median opposite the angles; composed of 7-9 outer cells, slightly thickened, and an inner layer of thin-walled cells around a small cavity.

Endodermis: Regular, elliptical cells, thickened on outer and lateral walls.

Vascular strand: Elliptical, V-B 2, spreading; a mass of thickened cells with cell contents lies on the upper part of the stele, subtending the arc of vascular tissue; xylem is divided into groups by the rays which traverse it and the phloem.

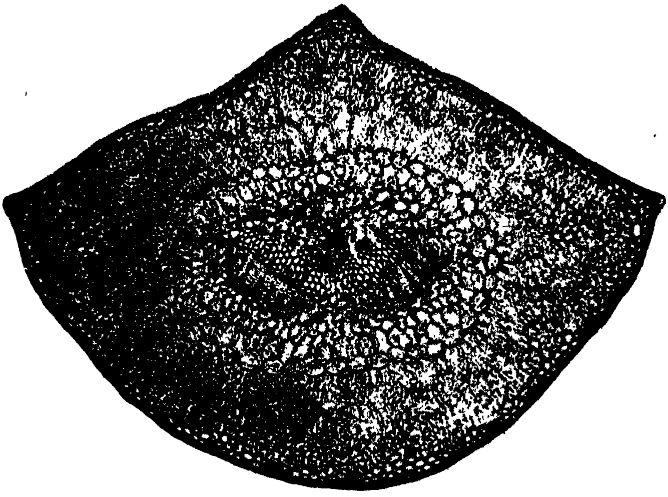


Fig. 35

SERIES IV—Five-needle Pines (leaf section a sector, triangular or 4-sided).

P. aristata. (Fig. 36.)

Comparative with: *P. canariensis*, which has stomata on all faces.

P. aristata is distinguished by its broad mesophyll of scarcely plicate cells and its characteristic leaf section outline.

Leaf section: Irregular sector.

Epidermis: Small, much thickened cells, with distinctly circular lumen, and a very thick cuticle layer.

Stomata: 3 + 3 on upper faces. Guard cells deeply sunk, thickened on both faces; the sunken opening bounded by the thickened edges of small epidermal cells.

Hypodermis: A row of regular, almost circular, collenchyma cells.

Mesophyll: A wide band 4-6 cells, large, only very slightly plicate.

Resin canals: 2 peripheral; of 16 outer thickened cells lined with disintegrated epithelium; the hypodermal cells are discontinued opposte the duct, which here adjoins the epidermal layer.

Endodermis: Elliptical, small, unthickened cells.

Vascular strand: Circular, lined by large-celled parenchyma; V-B single; adjoining the phloem is an arc-shaped layer of somewhat thickened cells with contents; much pitted transfusion tissue on upper flanks.

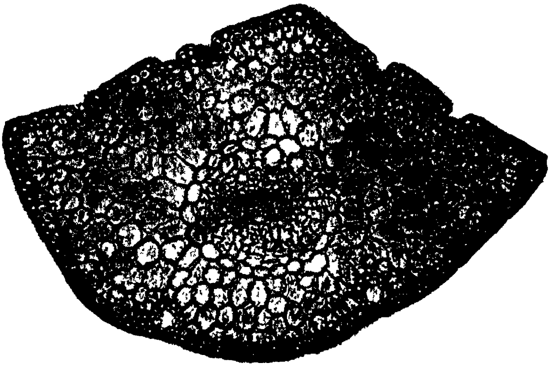


Fig. 36

P. Armandi (Rotorua). (Fig. 37.)

Comparative with: *P. Lambertiana* and *P. flexilis,* which have stomata on all faces.

P. strobus, which has 2 resin ducts and stomata in pairs or threes.

P. excelsa, which has 2 ducts and stomata in fives.

P. Montezumae, which has median ducts.

Leaf section: Triangular.

Epidermis: Regular on lower surface, irregular and broken on upper faces on account of protruding cells between the closely placed stomata.

Stomata: 4-5 + 4-5 on upper faces only. Guard cells thickened on both surfaces, slightly sunk, to the level of the hypoderm layer.

Hypodermis: 1 row of water layer cells.

Mesophyll: 2 rows of plicate, hexagonal cells on upper surfaces, 1 row, with palisade arrangement, on the lower face.

Resin ducts: 2 peripheral on lower face, sometimes an extra median duct placed at the upper angle; ducts of 1 row of 6 thin-walled cells, lined with epithelium.

Endodermis: Of large, almost circular cells, with sclerosed dividing wall.

Vascular strand: Circular; V-B single, occupying practically all the stele; but surrounded by a thin-walled parenchyma layer of large cells.

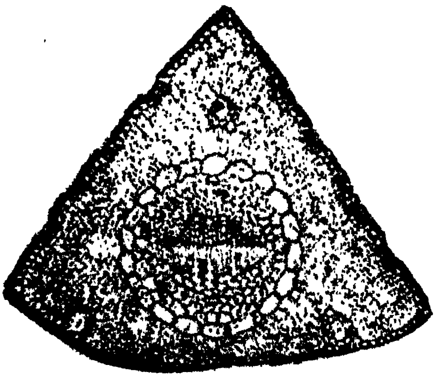


Fig. 37

P. excelsa. (Fig. 38.)

Comparative with: *P. strobus*, which has fewer stomata.
P. flexilis, which has no water layer.
P. Montezumae, which has median resin ducts.
P. Lambertiana, which has stomata on all faces.

Section: Triangular, sometimes 4-sided, with enlarged epidermal cells marking the angles.

Epidermis: Very small, thick-walled cubical cells.

Stomata: 5 + 5 on upper faces only. Slightly sunk; epidermal bounding cells protruding when open.

Hypodermis: 1 row of thin-walled water layer of flattened cells.

Mesophyll: Large, plicate cells.

Resin ducts: 2 peripheral; of large, almost circular, cells thickened on outer and adjacent walls; 1 row of lining cells.

Vascular strand: Circular; vascular bundle single, surrounded by fairly thick-walled parenchyma, with a mass of thin-walled tissue subtending the protoxylem.

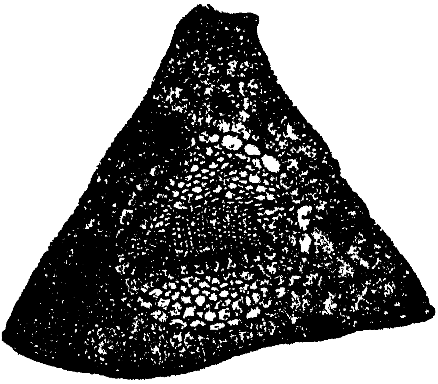


Fig. 38

P. flexilis (Rotorua). (Fig. 39.)

Comparative with: This species differs from *P. Montezumae, P. leiophylla,* and *P. taeda* in having peripheral ducts; from *P. strobus* and *P. excelsa* in having stomata on all faces; from *P. Lambertiana* in having no water layer.

Leaf section: Triangular.

Epidermis: Small, thick-walled cells, radially flattened.

Stomata: 3 + 3 + 3 borne on all faces. Guard cells slightly sunk, thickened on both faces.

Hypodermis: 1 layer of sclerosed fairly regular cells, increased at angles.

Mesophyll: Shortly plicate, 4 lobed cells.

Resin ducts: 2 peripheral, on lower face; 1 row of thickened cells and an inner thin-walled layer.

Endodermis: Elliptical cells, with thickening on the lateral walls between the cells.

Vascular strand: Circular; V-B single, surrounded by thin-walled parenchyma, a few transfusion cells flanking the phloem; 2 or 3 " rays " visible in phloem and xylem.

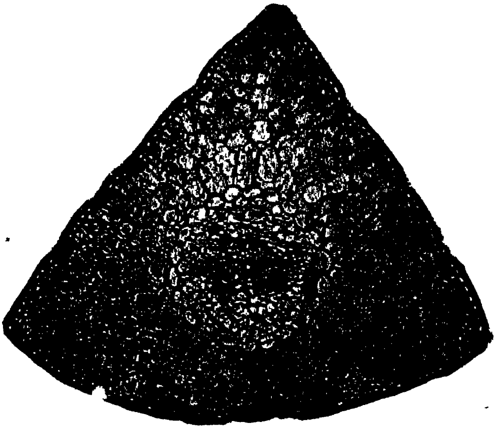


Fig. 39

P. Lambertiana (Rotorua). (Fig. 40.)

Comparative with: *P. flexilis,* which has no water layer.

P. strobus and *P. excelsa,* which have stomata only on upper faces.

P. Montezumae, which has median resin ducts.

Leaf section: Triangular or 4-5-sided, the angles defined by enlarged epidermal cells.

Epidermis: Small flattened, oval cells, with much thickened walls; the cells adjoining the stomatic opening are prolonged into a rounded beak, which probably form the ridges felt on the leaf surface.

Stomata: 2-3 + 2-3 + 3 on all faces. Guard cells slightly sunk, walls strengthened on both faces; large posterior air spaces, bounded by several cells.

Mesophyll: Large, slightly plicate, circular cells, with slight palisade infoldings on all faces.

Hypodermis: One row of pseudo water layer.

Resin ducts: 2 on lower face and sometimes 1 in upper angle, peripheral; surrounded by a row of uneven sized cells, a thinner walled continuation of the hypoderm layer, and lined by thin-walled epithelium.

Endodermis: Elliptical cells with distinct sclerosis of adjacent walls.

Vascular strand: Circular, V-B single, surrounded by large-celled, thin-walled parenchyma, with scattered cells of transfusion tissue (with bordered pits) on flanks of bundle.

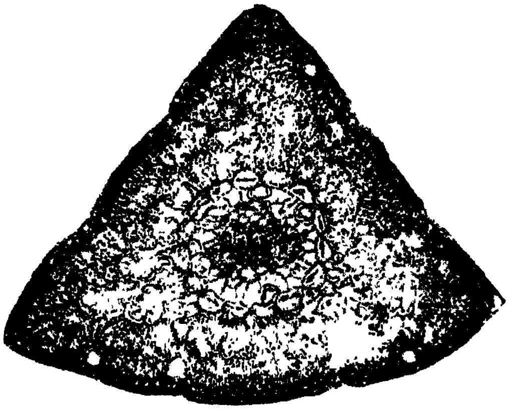


Fig. 40

P. Montezumae. (Fig. 41.)

Comparative with: *P. leiophylla,* which has no definite sclerenchyma layers.

P. excelsa, P. strobus, and *P. flexilis,* with peripheral ducts.

P. Armandi, with peripheral ducts and stomata only on two faces.

Leaf section: Triangular or 4-sided.

Epidermis: Small, oval, much thickened cells.

Stomata: 2 + 2 + 4; not sunk; guard cells thickened on both faces.

Hypodermis: An irregular layer of thin-walled water layer cells and 1 inner row of sclerosed, large cells, with contents, increased only at angles.

Mesophyll: 2 rows of plicate cells.

Resin ducts: 2 median, at the lower angles; of about 10 slightly thickened cells, with internal epithelial layer..

Endodermis: Irregular circular cells, thickened on outer walls.

Vascular strand: Circular; with 2 small vascular bundles, the phloem subtended by a line of sclerosed cells.

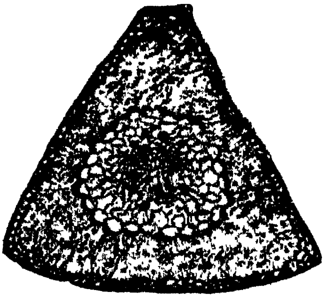


Fig. 41

P. monticola. (Fig. 42.)

Comparative with: *P. Lambertiana*, which slightly resembles *P. monticola*, but the latter can be easily identified by its 3 large marginal ducts, each with a diameter of about $\frac{1}{7}$ of the leaf diameter.

Leaf section: 5-sided, sometimes 4-sided.

Epidermis: Very small, rounded cells, protruding between stomata and giving an irregular outline.

Stomata: 4 + 4 on lateral faces; the short upper faces bear no stomata; nil on lower face. Guard cells sunk, thickened on both faces; the cells bounding the outer passage somewhat sunk and with a protruding tip.

Hypodermis: 1 row, occasionally increased to 2 rows, of sclerenchyma cells.

Mesophyll: 3 rows of regular, plicate, 6 lobed cells, with slight palisade infoldings on all faces.

Resin ducts: 3 peripheral; 1 row of flattened and thickened cells surrounding a large cavity.

Endodermis: Elliptical, distinct cells, thickened on outer and lateral walls.

Vascular strand: Circular, V-B single; the xylem subtended by an arc of sclerenchyma and flanked by transfusion tissue; a mass of albuminous cells adjoins the phloem, distinct " rays " traversing xylem and phloem.

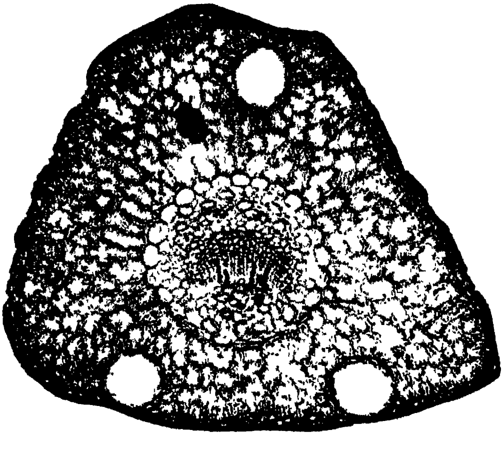


Fig. 42

P. strobus (Rotorua). (Fig. 43.)

Comparative with: *P. excelsa,* which has stomata in fives.

P. flexilis, which has no distinct water layer and stomata on lower face.

P. Montezumae, which has median resin ducts.

P. Lambertiana, which has stomata on all faces.

Leaf section: Triangular.

Epidermis: Ovate cells, cuticularised, and much thickened, with reduced lumen.

Stomata: 3 + 3 on upper faces only. Guard cells slightly sunk to level of hypoderm layer.

Hypodermis: 1 layer of slightly thickened cells, not increased at the angles.

Mesophyll: Almost circular, infolded to form five lobes; a distinct palisade layer on all faces.

Resin ducts: 2 peripheral on lower surface; fairly large, with 1 slightly thickened row of cells, lined by an epithelial layer.

Endodermis: Elliptical cells, slightly thickened on outer and adjacent walls.

Vascular strand: Circular; V-B single, surrounded by thin-walled, large-celled parenchyma; immediately adjoining the phloem are a few scattered large cells filled with contents, probably reserve storage (albuminous cells); traversing xylem are 2-3 "rays" of cells with contents, continued into the phloem.

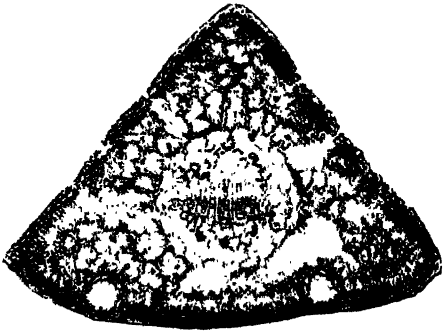


Fig. 43

P. Torreyana (Rotorua). (Fig. 44.)

Differs from all other species with triangular leaf sections by its characteristic, large size.

Leaf section: Triangular.

Epidermis: Regular, square cells, with thickened walls and reduced lumen.

Stomata: 7-8 on each surface. Guard cells sunk below hypodermis, outer wall thickened, opening cup-shaped, flanked by elongated, oblong epidermal cells.

Hypodermis: 3-4 rows of sclerosed irregular cells.

Mesophyll: Plicate, 6 lobed cells, with distinct palisade infoldings.

Resin ducts: 3 median, placed at the angles; each consists of 2 rows of thin-walled cells lined with epithelium.

Endodermis: Elliptical cells, thickened on outer and lateral walls.

Vascular strand: Circular; V-B 2, connected by thin-walled parenchyma; a bar of thin-walled empty cells joins the bundles opposite the phloem; and an arc-shaped mass of similar parenchyma cells faces both bundles opposite the xylem.

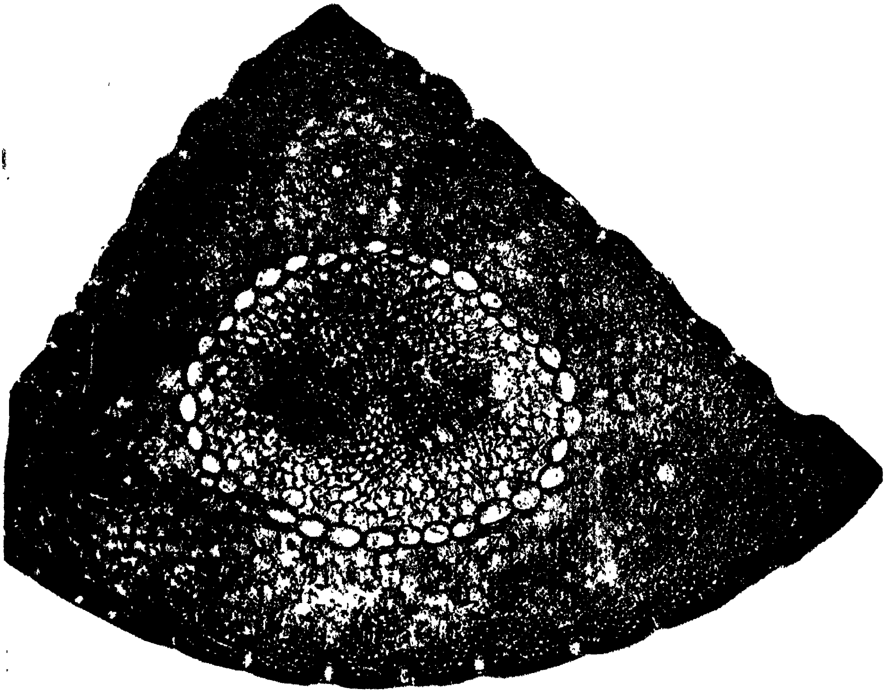


Fig. 44

ACKNOWLEDGMENTS.

The writer is glad to acknowledge here the assistance of Forest Guards Forbes and Johnston in the preparation of the microphotographs, and also the help given by Messrs W. Barker, S. Gibson, and S. Masters, of the State Forest Service, in the scale enlargement of all the plates, while thanks are due to Professor Kirk, Victoria College, for granting permission and facilities, and to Messrs C. E. Palmer, M.Sc., and J. S. Reid, B.Sc.,

INDEX AND SUMMARY OF LEAF CHARACTERS.

Fig.	Species.	Cross Section of Needle.	No. and Position of Resin Ducts.*	No. of Stomatic Lines		Nature
				Upper Surface.	Lower Surface.	Water Layer.
Series I—Single-needle Pines (leaf section circular).						
4	*P. monophylla* - - -	C	2P	29	—	—
Series II—Two-needle Pines (leaf section semi-circular).						
5	*P. austriaca* - - - -	½C	14M	8	12-14	—
6	*P. Banksiana* - - -	½C	2M	6	9	1
7	*P. densiflora* - - -	½C	7-10P	7	10	1
8	*P. echinata* - - - -	½C	2M	11	15	1
9	*P. halepensis* - - -	½C	1M; 6P	3	6	
10	*P. laricio (nigra* var. *calabrica)* - - -	½C	8-10M; 3I	9	10	—
11	*P. luchuensis* - - -	½C	2M	6	9	—
12	*P. Massoniana* - - -	½C	6-8P	6, 8	8-10	—
13	*P. muricata* - - - -	½C	3M	8	11	1
14	*P. Murrayana (contorta* var. *latifolia)*	½C	nil	7	11	1
15	*P. pinaster*—Rotorua -	½C	9M	8	15	1
	P. pinaster — Wellington - - - - -	½C	2M	8	15	—
16	*P. pinea* - - - - -	½C	nil	6	9	—
17	*P. resinosa* - - - -	½C	2-4P; 2M	7	10	1
18	*P. sylvestris* - - - -	½C	8P	9	9	1
19	*P. Thunbergii* - - -	½C	2-3M	8	12	1
Series III—Three-needle Pines (leaf section a sector or triangular).						
20	*P. canariensis* - - -	S	2P	3, 3	3	—
21	*P. caribaea* - - - -	S	4I	5, 5	12	1
22	*P. caribaea* - - - -	½C	2M; 2I	11	15	1
23	*P. Coulteri*—Rotorua -	S	2-4M	5, 5	12	—
	P. Coulteri — South Island - - - -	S	6M	7, 7	19	1?
24	*P. leiophylla* - - -	3 or 4	2M	4, 3	4	1-2
25	*P. palustris* - - -	S	2I	3, 4	10	—
26	*P. patula* - - - -	S	2M; 2I	3, 3	6	1
27	*P. ponderosa* - - -	S	3M	3, 3	8	—
28	*P. Jeffreyi* - - - -	S	3M	5, 6	7	1?
29	*P. scopulorum* - - -	S	4M	5, 5	10	1
30	*P. radiata* - - - -	S	2M	5, 5	9	1
31	*P. rigida* - - - - -	S	2-3M	7, 7	9	1?
32	*P. Sabiniana* - - -	S	2M	3, 3	6	—
33	*P. taeda* - - - - -	S	2M	9, 9	9-15	1
34	*P. tuberculata* - - -	S	2M; 3I	5, 5	8	1
35	*P. yunnanensis* - -	S	2M; 6P	3, 3	10	1?
Series IV—Five-needle Pines (leaf section triangular, a sector or five-sided)						
36	*P. aristata* - - - -	S	2P	3, 3	—	—
37	*P. Armandi* - - -	3	2P.; 1M	4, 4	—	1
38	*P. excelsa* - - - -	3 & 4	2P	5, 5	—	1
39	*P. flexilis* - - - -	3	2P	3, 4	3	—
40	*P. Lambertiana* - -	3 & 4	2-3P	2, 2	2	1?
41	*P. Montezumae* - -	3 & 4	2M	2, 3	4	1
42	*P. monticola* - - -	5	3P	4, 4	—	—
43	*P. strobus* - - - -	3	2-3P	3, 3	—	1
44	*P. Torreyana* - - -	3 & 4	3M	8, 7	9	—

*I = internal; M = median; P = peripheral.

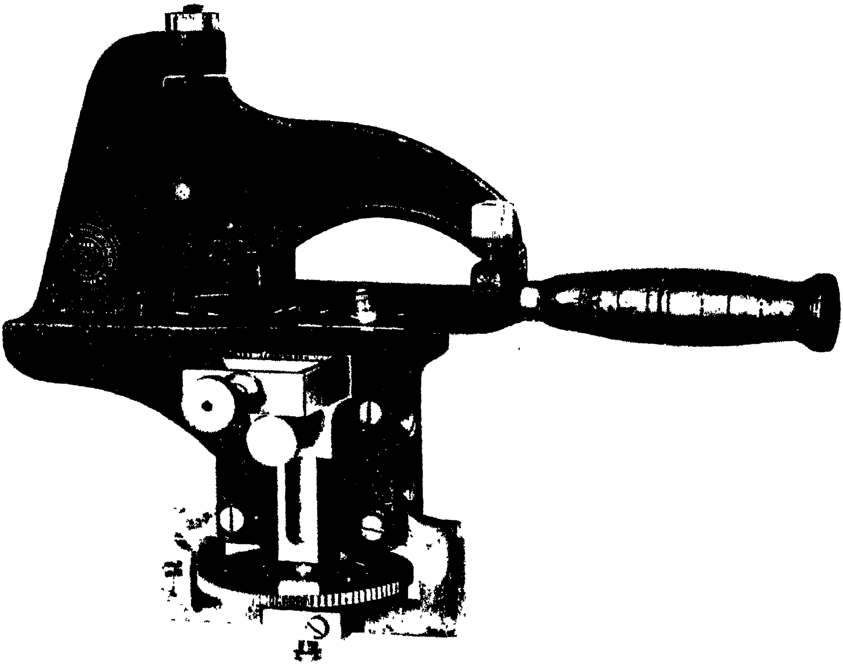


FIG. 1.—Swinging microtome fitted with special knife.

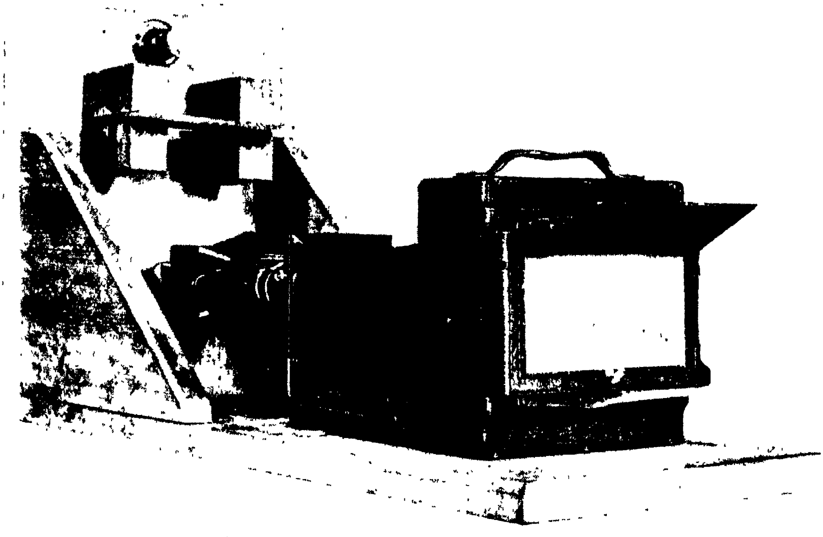


FIG. 2.—Photomicrographic apparatus.

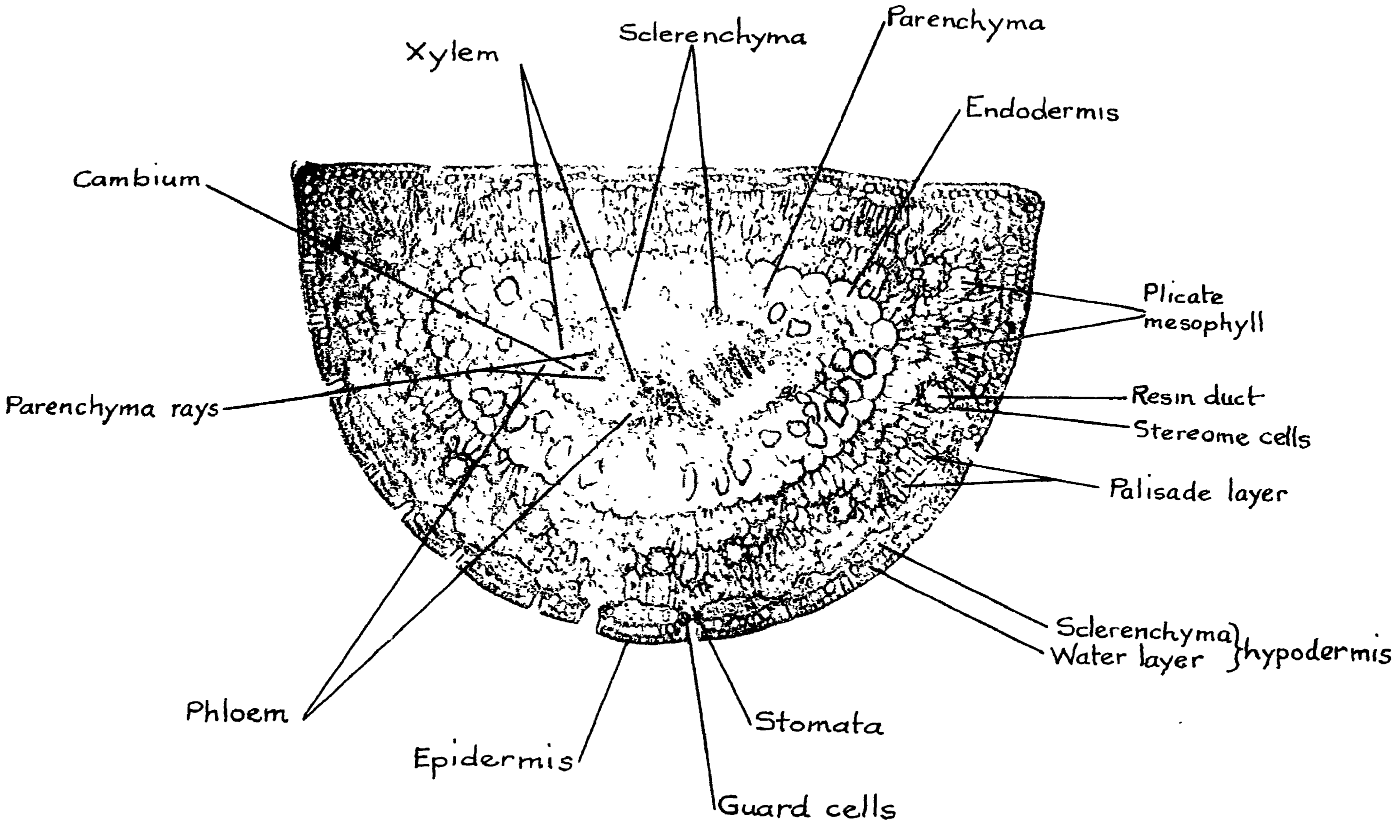


Fig. 3.—Transverse section of a typical pine leaf *(P. pinaste*

Fig. 3

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